JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLI, NO. 5. 76TH YEAR. MAY, 1901

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

ANTARCTICA: A HISTORY OF ANTARCTIC DISCOVERY.*

BY EDWIN SWIFT BALCH.

(*Continued from p. 262.*)

Captain George Powell was at the Shetlands in November, 1821. D'Urville† says that Powell left Elephant Island on December 4, 1821, in company with Palmer, and that on the 6th they discovered the Orkneys, Powell sighting them first. On the 12th they named Washington Strait. D'Urville quotes Laurie as follows: "Les terres Trinity Land et

*Copyright 1900, by Edwin Swift Balch.

† "Voyage au Pôle Sud," Tome Deuxième, pages 13–16.

It is a singular fact that Powell appears to have received more recognition from the French than from his own countrymen. An account of his life may be found in the "Biographie Universelle, Supplément," Paris, L. G. Michaud, 1845. This gives the title of a paper, which I have not seen: "Chart of New South Shetland, with the Islands discovered in the sloop 'Dove,' George Powell, Master, Accompanied by a Memoir, 1822." [Laurie, London, November, 1822.]

Jules de Blosseville, Lieutenant de Vaisseau, wrote a long appreciative notice of Powell: "Mort du Capitaine Georges Powell;" *Revue des Deux Mondes*, III année, Tome I, Paris, 1831, pages 38–46. This Lieutenant de

Tower Island des premières cartes, par la position d'environ 63° ½ S. et 60° ½ sont abandonnées comme imaginaires, ou n'étant seulement que des montagnes de glace." D'Urville deduces from this that the name Palmer Land and not Trinity Land is the proper one for the north coast of the mainland. According to the track laid down on the English Admiralty charts, Powell approached Palmer Land only once, where he was nearly 1° north of Mount Hope, in about 62° 30′ south latitude and 57° west longitude.

Captain Weddell* made numerous sealing voyages in 1820–1823. He searched for the Aurora Islands, and concluded that they were really the Shag Rocks, in 53° 48′ south latitude, 43° 25′ east longitude. He visited the Shetlands several times and called one of them Smith's Island and another James' Island; from his chart, he appears always to have been on their north or eastern shore.

In February, 1823, Weddell, in the brig "Jane," and Mr. Matthew Brisbane, in the cutter "Beaufoy," made an important southern cruise. Standing south on the 4th of February, they were deceived by great ice islands into thinking they had sighted land. On the 14th, in 68° 28′ south latitude, 29° 43′ west longitude, the ice islands were so numerous as almost to prevent the ships passing. On the 16th, on the contrary, in 70° 26′ south latitude, 29° 58′ west longitude, "ice islands had almost disappeared, and the weather became very pleasant."† On the 18th the ships were in

---

Blosseville must be the one lost in 1833 in the "Lilloise," on the East Greenland coast. See *Geographical Journal*, Vol. XVI, 1900, page 662.

Mr. P. Lee Phillips, Chief Map Division, Library of Congress, informs me that in Alexander G. Findlay's "A Directory for the Navigation of the Pacific Ocean," printed for R. H. Laurie, London, 1851, Part II, pages 658–660, there is an account of the Orkneys prepared from Powell's notes. Mr. Phillips also says that in *Journal des voyages découvertes et Navigations Modernes* (publié par Verneur et Frieville, 44 vols., Paris, 1818–30), 1824, Vol. 22, and in *Annales Maritimes*, 1824, Vol. I, there is an article entitled "Extrait des Voyages du Capitaine Powell à S. Shetland," 1821–1822. I have not been able to find these books.

*"A Voyage Towards the South Pole," performed in the years 1822–24. By James Weddell, Esq., Master in the Royal Navy. London: Longmans, Hurst, Rees, Orme, Brown and Green, 1825.

†"A Voyage," etc., page 34.

latitude 72° 38′ south. "In the evening we had many whales about the ship, and the sea was literally covered with birds of the blue peterel kind. *Not a particle of ice of any description was to be seen.* The evening was mild and serene."* On the 19th the ships were in latitude 73° 17′ south, longitude 35° 54′ west. On the 20th: "At 10 o'clock in the forenoon, when the ship's head was E. S. E., I took a set of azimuths, which gave variation 11° 20′ east. The atmosphere now became very clear, and nothing like land was to be seen. Three ice islands were in sight from the deck, and one other from the masthead. On one we perceived a great number of penguins roosted. Our latitude at this time, 20th February, 1822, was 74° 15′, and longitude 34° 16′ 45″; the wind blowing fresh at south, prevented, what I most desired, our making further progress in that direction. I would willingly have explored the S. W. quarter, but taking into consideration the lateness of the season, and that we had to pass homeward through 1,000 miles of sea strewed with ice islands, with long nights and probably attended with fogs, I could not determine otherwise than to take advantage of this favorable wind for returning.† * * * These considerations induce me to conclude, that from having but three ice islands in sight, in latitude 74°, the range of land, of which I have spoken, does not extend more southerly than the 73d degree. If this be true, and if there be no more land to the southward, the antarctic polar sea may be found less icy than is imagined, and a clear field of discovery, even to the South Pole, may therefore be anticipated."‡ Captain Weddell then sailed northward, on a course not far distant from his southerly one. His southern cruise is interesting, and what he says about warmer weather and little ice far south agrees with what Morrell reports of the same season. Weddell called his open sea "George IV Sea," but geographers are beginning now, with justice, to chart it as "Weddell Sea."

---

* "A Voyage," etc., page 36.
† "A Voyage," etc., page 37.
‡ "A Voyage," etc., page 43.

Morrell wrote a brief notice of Weddell, about whom he says:* "Captain James Weddell, of the British Navy, whom I have before mentioned in the previous chapter, as seeking for the Aurora Islands in 1822: a most excellent officer, and a highly worthy man: justly extolled as an active, correct and enterprising navigator. Being familiar with danger in its most appalling form, every emergency finds him cool, steady and undaunted. He is, in short, at once an honour to his country and to human nature. I speak with confidence, for I know him."

Captain Robert Johnson, in 1822, made a sealing cruise in the schooner "Henry," of New York. Captain Morrell writes about him:† "The schooner 'Henry,' Captain Johnson, who had been vainly cruising for six weeks in search of the Aurora Islands, returned to New Island on Wednesday, the 23d. (Note. The history of these *imaginary* islands will be found on a subsequent page.)" And later: "March 15th. * * * At this time the wind had hauled to the southwest, and at half-past four P.M. we were close in with the eastern coast of the land to which Captain Johnson had given the name of New South Greenland." ‡

Edmund Fanning also speaks of Captain Johnson:§ "This continent, it is asserted in Morrell's voyage, page 69, was named 'New South Greenland' by a Captain Johnson. It is but just to state here, that this most meritorious mariner (Captain Johnson) was a pupil to, and made his first voyage to the South Seas with, the author, with whom also he remained, rising to different stations, and finally became one of his best officers; the first information he obtained of the discovery of this land by Captains Pendleton and Palmer was from the author of this work."

Captain Johnson made another cruise in the year 1824 or 1826. "From this voyage he never returned. He was last seen at the South Cape of New Zealand, in the following year, having lost three men, who were drowned at Chatham

* "A Narrative of Four Voyages," etc., page 68.
† "A Narrative of Four Voyages," etc., page 53.
‡ "A Narrative of Four Voyages," etc., page 69.
§ "Voyages Round the World," etc., page 437.

Islands. * * * My informants further stated, that the 'Henry' left New Zealand on a cruise to the south and east, in search of new lands, between the sixtieth and sixty-fifth degrees of south latitude; and as he has never been heard of since leaving New Zealand, it is very probable that he made discovery of some new island near the parallel of 60 on which the 'Henry' was shipwrecked."*

Captain Benjamin Morrell, in the sealing schooner "Wasp," of Stonington, made a voyage to Antarctica in 1822–23.† He reached the Falklands on October 16th, then made a fruitless search for the Auroras, and afterwards steered for South Georgia. Thence he sailed for Bouvet Island, which he reached on December 6th and where he caught many seals. He gives its position as 54° 15′ south latitude, 6° 11′ east longitude. Sailing from there southward his ship was nipped on December 13th in 60° 11′ south latitude, 10° 23′ east longitude. After extricating himself, he sailed to Kerguelen Island, where he spent some time sealing. On January 11th he steered south and east, and in 62° 27′ south latitude, 94° east longitude, fell in with ice fields measuring at least 150 miles east and west. He continued east until February 1st, when he reached 64° 52′ south latitude, 118° 27′ east longitude. The wind now came fresh from the northeast, and Morrell turned west; "being, however, convinced that the farther we went south beyond 64° the less ice was to be apprehended, we steered a little to the southward until we *crossed the Antarctic Circle*, and were in latitude 69° 11′ S., long. 48° 15′ E. In this latitude there was *no field ice*, and very few ice islands in sight." He continued steering west until, on February 23d, he crossed the meridian of Greenwich in 69° 42′ south latitude. He now steered north and west for Sandwich Land.

After a short stay at Sandwich Land, Morrell left there

* "A Narrative of Four Voyages," etc., pages xxiii and 363.

† "A Narrative of Four Voyages to the South Sea, North and South Pacific Ocean, Chinese Sea, Ethiopic and Southern Atlantic Ocean, Indian and Antarctic Ocean," from the year 1822 to 1831. By Capt. Benjamin Morrell, Jun.; New York: J. & J. Harper, 1832, pages 59–69.

on March 8th, steering south and west. He was nearly caught by field ice, but broke through, and on March 14th reached 70° 14′ south latitude, 40° 3′ west longitude. Here the sea was free from field ice, and there were not more than a dozen ice islands in sight. The temperature of the air was 47° F., and of the water 44° F., both of which were higher than further north. Morrell also says that on the several occasions on which he crossed the antarctic circle he found the temperature both of the air and of the water became milder the farther he advanced beyond 65° south latitude.

From his most southerly point Morrell turned northwest, giving as his reasons for not penetrating further that he had no fuel and was short of water. On March 15th, in the afternoon, "we were close in with the eastern coast of the body of land to which Captain Johnson had given the name of New South Greenland." On March 16th the boats searched for seals on the coast, "the vessel following or keeping abreast of them, about two miles from the land, until the next day at 4 P.M. when we were in lat. 67° 52′ S., long. 48° 11′ W. * * * The coast here tended about S. E. by S., and we thought we could discern some of the mountains of snow, about seventy-five miles to the southward." Morrell then stood to the north.

Morrell has been severely assailed, for instance by D'Urville, Commander J. E. Davis, R.N.,* Dr. Fricker, etc. Some authors give as a reason for disbelieving in Morrell that his book is *rare*. At any rate there are two copies in the Philadelphia Library. It has also been said that his book "was withdrawn soon after Biscoe's discoveries were made known;" but as no authority is given for the statement, this needs confirmation. Captain (now Sir) R. V. Hamilton † wrote an able defence of Morrell, in which he said,

* In answer to Captain Hamilton. Commander Davis is the author of a paper: "On Antarctic Discovery and its Connection with the Transit of Venus in 1882;" *The Journal of the Royal Geographical Society*, Vol. XXXIX, 1869, pages 91–95.

† "On Morrell's Antarctic Voyage in the Year 1823," etc. *Proceedings of the Royal Geographical Society*, 1870, Vol. XIV, pages 145–156.

inter alia, "whatever else Mr. Morrell might not have discovered, he was the first discoverer of guano in the island of Ichaboe and Lobos. The speed of 120 miles a day, with which he made the voyage, was nothing uncommon as the sea was not encumbered with ice. * * * Mr. Morrell was a sealer, not an educated man, and therefore due allowance must be made for his errors." Dr. A. Petermann* appears to have believed in Morrell, for he says: "about the longitude there is probably a correction to be made of at least 5° to the west." Sir John Murray marks Morrell's positions on his map† apparently with Dr. Petermann's correction for longitude. Professor Angelo Heilprin‡ likewise appears to consider Morrell trustworthy. Certainly some of Morrell's statements are hard to believe, and yet they are just possible. He may have reached 64° 52′ south latitude, 118° 27′ east longitude, and not seen the land. When he speaks of New South Greenland he refers almost surely to the western mainland. The two phrases, on March 15th and 16th, "we were close in with the eastern coast," and "the coast here tended about S. E. by S.," are noteworthy. For how did Morrell know that there was an eastern coast, if he had not been there? There may be an earlier mention of the eastern coast than that of Morrell, published in 1832, but if so, I have not come across it. This coast is not indicated on Weddell's chart nor on Vandermaelen's Atlas.§ Morrell's book is a bad and cheap piece of printing, and an error of a figure may easily have crept into the statement of longitude: 48° 11′ west, for 58° 11′ west. The proof of Morrell's statements about the Antarctic seems to lie in the sentence "and were in lat. 69° 11′ S., long. 48° 15′ E." If correct, then Enderby Land is an island

---

* Petermann, A.: "Neue Karte der Süd Polar Regionen; *Mitteilungen aus Justus Perthes Geographischer Anstalt*," etc., von Dr. A. Petermann, 1863, pages 407–428. Page 415.

† Murray, John, Ph.D., LL.D.: "The Exploration of the Antarctic Regions;" *Scottish Geographical Magazine*, Vol. II, 1886, pages 527–548.

‡ Heilprin, Professor Angelo: "Our Present Knowledge of the Antarctic Regions;" *Popular Science Monthly*, New York, 1897, pages 323–336.

§ Vandermaelen, Ph.: "Atlas Universel de Géographie," Bruxelles, 1827.

or non-existent, and certainly the reports of the "Pagoda," the "Challenger," and the "Valdivia" show that further exploration in that quarter is necessary. Although Morrell's book is of little value as a scientific record, still it should be remembered in Morrell's favor that he was a sealer and not a scientist, that he had no instruments of precision, that the summer of 1823 was the most open in Antarctic records, and that even then Morrell does not claim to have reached as high a southern latitude as Weddell in the same year.

A Captain Hoseason (American?), according to D'Urville,* while seal hunting in 1824, may have discovered and given the names to Hughes Bay, Intercurrence, Three Hummock and Hoseason Islands, and Point Farewell. This seems to be rather in the nature of a guess on the part of D'Urville.

Captain Norris,† with the "Sprightly" and "Lively," belonging to Messrs. Enderby, on December 10, 1825, sighted an island in 54° 15′ south latitude, 5° east longitude. He called it Liverpool Island, but it is doubtless Bouvet Island. On the 13th he sighted another small island in 53° 56′ south latitude, 5° 30′ east longitude, which he called Thompson Island.

Captain Henry Foster, R.N., in 1828–1829, commanded an expedition to the South Shetlands‡ for the purpose of making pendulum observations. After stopping at Staaten Land, where he met Captain Nathaniel B. Palmer, he sailed to the Shetlands and beyond to a place which he named

---

* "Voyage au Pôle Sud," Tome Deuxième, page 20.

† Ross, Sir J. C.: "Voyage," etc., Vol. II, pages 371, 372.

‡ "Narrative of a Voyage to the Southern Atlantic Ocean," in the years 1828–29–30, performed in H. M. sloop "Chanticleer," under the command of the late Captain Henry Foster, F.R.S., etc. From the private journal of W. H. B. Webster, surgeon of the sloop. London, Richard Bentley, 1834.

The Journal of the Royal Geographical Society of London for MDCCCXXX–XXXI, London, MDCCCXXXI: VI.—"Account of the Island of Deception, one of the New Shetland Isles." Extracted from the private journal of Lieutenant Kendal, R.N., embarked on board his Majesty's sloop "Chanticleer," Captain Forster (*sic*), on a scientific voyage; and communicated by John Barrow, Esq., F.R.S. Read 24th January, 1831.

Possession Cape* in 63° 43′ south latitude, 61° 45′ west longitude, and on which he landed. Lieutenant Kendal thinks this was a new discovery, but he is clearly in error. The "Chanticleer" was then moored in the harbor (Yankee Harbor) of Deception Island on January 9, 1829, and remained there until March 4th, and during her stay numerous pendulum observations were made. The island is volcanic; some of the mountain peaks emitted smoke; and numerous hot springs bubbled up on the shores and the beaches.† Dr. Webster and Dr. Peter Conolan studied the fauna and flora of Deception Island.‡ They were much struck with the enormous abdominal vein of the leopard-seals.

Dr. Webster says of icebergs: "Having made some experiments of this nature,§ I deduced from them that in cubic pieces of ice one-seventh part only remained above the surface of the water. I also placed a cone of ice on a cubic piece from the same iceberg, and found that the cube easily floated and sustained the little pyramid, the height of which was more than double the depth of the cube below the water. I also floated irregular-shaped masses, and found their heights above the surface to vary considerably; in some it was equal, in others greater than the depth below it; proving that no inference can be safely drawn as to the depth to which an iceberg extends from the surface with reference to its height above it, and that all depends on its form. * * * In corroboration of this I may further observe, that while we were in contact with the iceberg off the island, we determined its height by a reference to the vessel's mast to be not less than fifty feet. Now this would have required a depth of three hundred and fifty feet to float in, according to the conclusion deduced from a cubical piece; but it was floating in ninety-six feet; for we obtained soundings at the same time with sixteen

* D'Urville thinks this may be Hoseason Island.

† "Narrative of a Voyage," etc., Vol. I, pages 144–168; Vol. II, pages 273–280.

‡ "Narrative of a Voyage," etc., Vol. II, pages 300–306.

§ "Narrative of a Voyage," etc., Vol. I, pages 142–143.

fathoms of line." These observations of Dr. Webster deserve to be better known, for even to-day, apparently, it is often believed that the height of an iceberg above water is six or seven times less than its depth under water; and Dr. Webster, it would seem, was the first to note that this was not always the case.

Captain James Brown,* an American sealer, made a southern voyage in 1829–31 in the schooner "Pacific." He reported sighting four islands which were, at the time, not charted. The first, in 56° 18′ south latitude, 28° 35′ west longitude, he called Potter's Island. The second, in 55° 55′ south latitude, 27° 53′ west longitude, he named Prince's Island. The third, in 56° 25′ south latitude, 27° 43′ west longitude, he christened Willey's Island; and the fourth, in 57° 49′ south latitude, 27° 38′ west longitude, he called Christmas Island.

Mr. John Biscoe, in 1830–32, with the brig "Tula" and the cutter "Lively," Captain Avery, both ships belonging to the Messrs. Enderby, circumnavigated Antarctica,† sailing eastward. In November, 1830, he searched in vain for the Aurora Islands. On January 7, 1831, in 59° 35′ south latitude, 20° 21′ west longitude, Biscoe was stopped by smooth pack ice, which seemed to have been formed at sea; "nevertheless there were strong indications of land in the southwest." On the 21st, in 66° 16′ south latitude, 0° 24′ west longitude, there were many indications of land to the south and southeast. On February 1st Biscoe was in 68° 51′ south latitude, 12° 22′ east longitude; and on the 25th, in 66° 2′ south latitude, 43° 54′ east longitude, where he "saw a very distinct appearance of land." "At length, on the 27th, in latitude 65° 57′ south, longitude 47° 20′ east, land was distinctly seen, of considerable extent, but closely

* "Fanning, Edmund: "Voyages Round the World," etc., pages 440–442.

† *The Journal of the Royal Geographical Society of London*, Volume the Third, 1833, pages 105–112; VIII.—"Recent Discoveries in the Antarctic Ocean." From the log-book of the brig "Tula," commanded by Mr. John Biscoe, R.N. Communicated by Messrs. Enderby. Read 11th February, 1833.

The Nautical Magazine for 1835, Vol. IV, Simpkin and Marshall, London; pages 265–275: "Voyage of the 'Tula' towards the South Pole."

bound with field ice." Efforts were made to close with the land, but owing to heavy gales the ships were driven off. On March 16th, however, "nearly the same land was again made; the longitude being now 49° E. A head-land, previously seen, was recognized, and called Cape Ann; and unceasing efforts were made, for some days, to approach nearer it, but all in vain." On April 6th Captain Biscoe finally turned north, "never having approached this forbidden land (which has, with great propriety, been called Enderby's Land) nearer than from twenty to thirty miles."

Biscoe sailed again south from New Zealand in January, 1832. He bore away southeast. On the 25th he was in 60° 45′ south latitude, 132° 7′ west longitude; on February 3d, in 65° 32′ south latitude, 114° 9′ west longitude; and on the 12th, in 66° 27′ south latitude, 81° 50′ west longitude; in all of which positions much ice was seen. On February 15th, in 67° 1′ south latitude, 71° 48′ west longitude, land was seen; this was called Adelaide Island; "and in the course of the ensuing fortnight, it was further made out to be the westernmost of a chain of islands, lying E. N. E. and W. S. W., and fronting a high continuous land, since called Graham's Land, which Captain Biscoe believes to be of great extent. The range of islands has been also since called Biscoe's Range, after the discoverer." "On the 21st of February Captain Biscoe succeeded in landing on what he calls the main land." The mountains here were named Mount Moberly and Mount William, the latter in 64° 45′ south latitude, 63° 51′ west longitude. Biscoe then repaired to the South Shetlands, and afterwards returned to England.

In 1833, an English sealer, named Kemp, is reported to have sighted land just east of Enderby Land, and it is marked "Kemp Land" on many atlases. Although Kemp's course is laid down on the English Admiralty charts, there is, apparently, no published account of his journey.*

---

* The sum total of added knowledge in these sixty years, judging from Hugh Murray's "The Encyclopædia of Geography" (Philadelphia, Carey, Lea & Blanchard, 1837, Vol. III, pages 172-173), had led to a general belief, in 1837, that round the South Pole was an archipelago of islands, and not a continental mass. Murray refers to the Antarctic under the title "South

Mr. John Balleny, an English sealer, sailed from Chalky Bay, New Zealand, on January 7, 1839, with the schooner "Eliza Scott," and the cutter "Sabrina."* He worked his way south, westward of 170° east longitude, and on February 1st was in 69° south latitude, 172° 11′ east longitude, where the pack was so thick that he turned north. On February 9th he discovered three islands in 66° 22′ south latitude, 163° 49′ east longitude, landed on one of them on February 12th, and found that it was volcanic in origin.

From these islands, since appropriately called the Balleny Islands, Balleny worked up northward and then westward. He met with a good deal of ice. His log says:

"*March 1st.*—With a steady breeze from the S. E. continued standing to the westward—passed several icebergs, and numerous flocks of penguins, petrels, and mutton birds.

"*March 2nd, A. M.*—Squally from the S. E., with snow and sleet. At 8 cleared off a little. At noon, lat. obs. 64° 58′, long. 121° 8′, therm. 35°. P. M., strong winds, and showers of snow and sleet; saw a great many birds. At 8, the water becoming smooth all at once, shortened sail, and hove-to. Saw land to the southward, the vessel surrounded by drift ice. At midnight strong breezes with snow.

Polar Islands," and begins: "The islands of the Southern Polar Sea, to which Monsieur Balbi gives the somewhat too pompous title of Antarctic Archipelago, extend chiefly," etc. He says also: "In 1831, Captain Biscoe fell in with land, in 66° S. lat. and 47° E. long., to which he gave the name of Enderby Land, and which he conceives to be of considerable extent. In the following year, he touched upon another coast of uncertain extent, in about the same latitude, and in long. 70° W. To this latter tract has been given the name of Graham Land." This paragraph of Murray is interesting, for it proves that the discovery of Enderby Land did not, at the time, give to geographers any idea of a South Polar Continent, but only that another island had been found. My attention was called to Murray's work by Mr. Edward E. Hale's "Stories of Discovery," Boston, Roberts Brothers, 1887.

* *The Journal of the Royal Geographical Society of London*, Volume the Ninth, 1839, pages 517–528; VI: "Discoveries in the Antarctic Ocean, in February, 1839." Extracted from the journal of the schooner "Eliza Scott," commanded by Mr. John Balleny. Communicated by Charles Enderby, Esq.

A brief note about the claims of Balleny as a discoverer is found in *Proceedings of the Royal Geographical Society of London*, Vol. II, 1858, pages 171, 172: "Note on Sabrina Land," etc., by Charles Enderby.

"*March 3rd, A. M.*—Found the ice closing and becoming more compact; stood through the drift ice to the southward. At 8 h. found ourselves surrounded by icebergs of immense size; to the S. W. the ice was quite fast, with every appearance of land at the back of it, but the weather coming on thick, were obliged to steer to the northward along the edge of the pack. At noon, lat. by obs. 65° 10′, long. 117° 4′. P. M., Fresh breezes from the S. S. E. and clear; numerous icebergs in sight."

The two sentences "saw land to the southward" and "the ice was quite fast, with every appearance of land at the back of it," are the only references to the great mass of land south of Australia.* Balleny never suggested nor evidently even suspected that he was on the edge of a continent, or that he had sighted anything but another island. That no one in England, at the time, thought the matter of any importance is shown by the fact that the editor of *The Journal of the Royal Geographical Society* placed as running heading at the top of page 525: "Sturge Island—Brown's Peak—Borradaille Island." Three of the Balleny Isles! There is nothing about Sabrina Land! This does not, however, alter the fact, and there appears to be no doubt that Balleny had a glimpse of the eastern mainland of Antarctica.

Balleny continued on his westerly course. On March 13th he wrote: "Light variable winds from the eastward; surrounded by icebergs: in lat. 61°, long. 103° 40′, passed within a ¼ of a mile of an iceberg about 300 feet high, with a block of rock attached to it."† About this his editor commented as follows: "We will, therefore, only add that this iceberg was distant 1,400 miles from the nearest *certainly*

* Sir James Ross says ("Voyage," etc., Vol. I, page 272) that the log of Balleny states that on February 26th they thought they saw land in 64° 40′ south latitude, 131° 35′ east longitude, but that they concluded it was fog.

† As a sort of appendix to this paper is: "VI. Note on a Rock Seen on an Iceberg in 61° South Latitude;" *The Journal of the Royal Geographical Society of London*, Vol. the Ninth, 1839, pages 528–529, by Charles Darwin. He thinks such transported boulders are rare in Antarctica, but that, nevertheless, "the bottom of the Antarctic Sea, and the shores of its islands, must already be scattered with masses of foreign rock,—the counterpart of the erratic boulders" of the northern hemisphere."

known land, namely Enderby's Land, which bore W. S. W. of it. But it is highly probable from the compact nature of the ice, etc., that land extends between the parallels of 66° and 68° S., in which case the iceberg would not be distant above 300 miles from this supposed land. The appearance of land seen by Captain Balleny on the 3d of March, as above mentioned, bore from the iceberg E. S. E., distant 450 miles." Balleny then returned to England, apparently without making any stops, so that his discovery could not have been known to either Wilkes or D'Urville when they sailed.

Captain Dumont D'Urville,* in January, 1838, with the "Astrolabe," and Captain Jacquinot, with the Zélée," sailed southward from the Strait of "Magalhaens." On January 15th they found the first icebergs, in about 59° 30′ south latitude. On January 22d, in about 64° south latitude, due south of the Orkneys, they were stopped by an icy barrier extending along the entire horizon. The *corvettes* followed the line of the pack for more than 200 kilometers, coming back to 61° south latitude, north of the Orkney Islands. D'Urville wished to follow the tracks of Weddell, and, therefore, turned once more southeast, when he again met an icy barrier between 62° and 63° south latitude. In trying to break through the pack, the vessels were nipped, and for five days were in a good deal of danger. Finally, a strong southerly gale opened the pack somewhat, and with the help of saws and axes, they succeeded in breaking loose. On February 15th D'Urville returned westward, examined again the Orkneys and some of the Shetlands, and then succeeded in getting a little further south, where between 63° and 64° south latitude he sailed over 100 kilometers along the coast of Palmer Land, which he renamed Louis Philippe Land and Joinville Land, although it had been previously visited by Palmer and Johnson. Scurvy having appeared on his ships, he then returned north.

* "Voyage au Pôle Sud et dans l'Océanie, sur les Corvettes 'l'Astrolabe' et 'la Zélée,'" sous le commandement de M. J. Dumont-D'Urville, capitaine de vaisseau. Publié par ordonnance de Sa Majesté, sous la direction supérieure de M. Jacquinot, capitaine de vaisseau: Paris, Gide et Cie, éditeurs, 1845; Tome Deuxième.

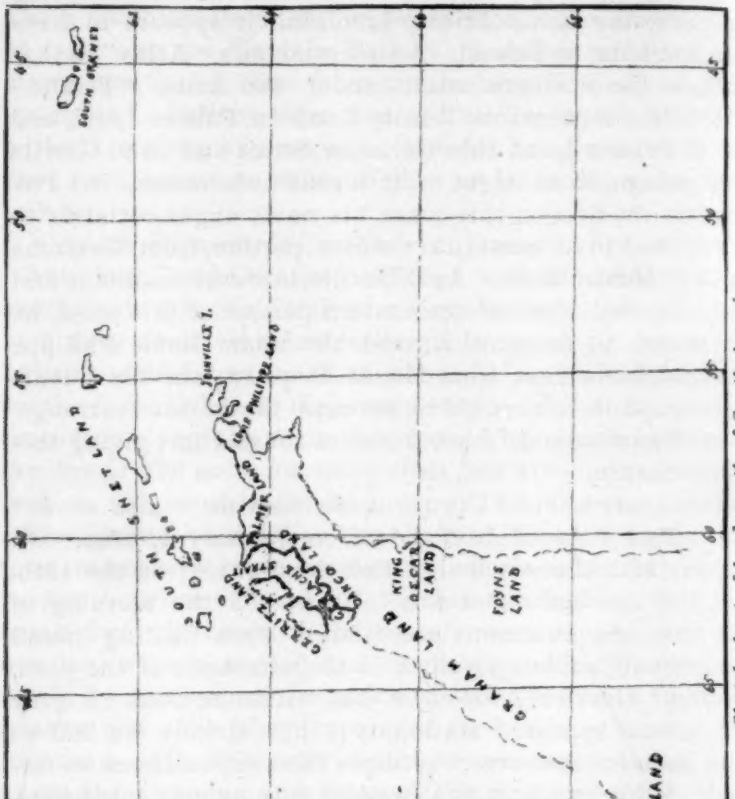
D'Urville mixed up the nomenclature of the western mainland of Antarctica. Before his visit, the northern coast was known to the Americans as Palmer Land, to the English as Trinity Land. I have found no record stating who gave the name Trinity Land, but it appears to have been used first by Powell. Vandermaelen's "Atlas" in 1827 outlines the northern coast under the name "Trinité." D'Urville simply wrote Trinity Land on Palmer Land, and moved Palmer Land into Gerlache Strait and on to Gerritz Archipelago, so as to get room for his own names. As Palmer was the first on this coast, his name ought certainly to be restored to at least its western portion, from Gerlache Strait to Mount Hope. As D'Urville, however, made the first fairly detailed chart of the eastern portion of this coast, he has claims to recognition, and the name Louis Philippe Land might be kept from Mount Hope to Joinville Island. It seems as if this would be perhaps the fairest rearrangement of names, and I have drawn a rough chart giving this nomenclature.

Two years later D'Urville made another cruise south.* He started from Hobart Town on January 1, 1840. On January 16th the watch signalled the first ice; on the 18th, they had reached 64° south latitude; on the morning of the 19th, six enormous ice islands were floating round them; finally, about 3 o'clock on the afternoon of the 19th, Monsieur Gervaize, who was on watch, noticed "a grey spot, which appeared stationary;† but already we had so often been led into error by these false appearances, so frequent in these regions, that we had become very suspicious. Monsieur Dumoulin, who was on deck, occupied at that instant in charting the various ice-islands which were in sight, hastened to ascend the rigging so as to clear up all doubts; he assured himself that the indications noted by Monsieur Gervaize had reference to a cloud, which, seen from the height of one of the spars (*hune d'artimon*), appeared to be above the horizon. On descending, he announced to

* "Voyage au Pôle Sud," etc., Tome Huitième, pages 123–185.

† "Voyage au Pôle Sud," etc., Tome Huitième, page 136.

me besides, that straight in front of us, there was an appearance of land much more distinct and more noticeable; it was, in fact, Adélie Land. Thanks to this circumstance,



Sketch chart of lands south of South America.

Monsieur Dumoulin was the first one of us all who saw the land."

On the 20th, owing to lack of wind, they could not get any nearer to the coast, and there remained, on the "Astro-

labe," more than one doubter as to its existence. But at midday all uncertainty ceased, as a boat sent from the "Zélée" announced that since the day before they also had seen land. On the 21st a light wind enabled the ships to close in with the shore. As they progressed, ice islands became more numerous, and by eight o'clock the *corvettes* were so hemmed in by these enormous masses of ice that D'Urville feared every instant seeing his ships wrecked. During the day, however, they worked their way through until they were in a small (Piner's) bay:

"The land which was in sight now showed us the few accidents it presented:* it stretched as far as the eye could see to the southeast and to the northwest, and in these two directions we could not see its limits. At no place did it show any rising summit. At no place either could one see any spot indicating the soil, and one might have thought that we had arrived before an ice-barrier still bigger than all those we had already met, if we could have been able to admit that ice-barriers ever could reach such a prodigious height. Its shore showed everywhere a vertical cliff of ice, similar to those we had observed in the floating islands we had been sailing past. This aspect of the coast was so exactly alike to the one which these floating bergs had shown us, that we did not retain the least doubt as to the formation of these latter. Moreover, on several points of the shore, we could see besides a good number of floating islands, which seemed barely separated from the land where they had formed and to be awaiting only the influence of the winds and of the currents to go out to sea. The elevated parts of the land showed everywhere an uniform tint; they ended at the sea by a gently inclined slope; thanks to this arrangement we could see a pretty considerable stretch of country. At several points, we noticed that the snows which covered the soil showed a broken and irregular surface. One could perceive regular waves, like those which the winds dig in sand deserts. It was especially in the least protected portions that these acci-

* "Voyage au Pôle Sud," etc., Tome Huitième, pages 143–145.

dents appeared strongest. At other spots, this crust of ice seemed also traversed by ravines or cut out by the waters. The sun shone in all its splendor and added greatly to the already so imposing aspect of this mass of ice. With our glasses we examined at every instant this mysterious land, whose existence it seemed could no longer be contested, but which had not offered to us as yet any absolutely certain proof of its existence."

Suddenly, however, some black spots were seen by Monsieur Duroch in the bay, and these turned out to be several small islands. Boats were sent from both *corvettes*, and some members of the expedition landed on one of the islands, on which they ran up the *tricolore* flag, and of which they took possession, as well as of the adjoining coast, in the name of France. The ceremony was concluded by drinking a bottle of Bordeaux wine. The little island was a bare rock, and did not offer the slightest trace of lichens. The animal kingdom was represented only by penguins, and not a single shell was found. "Up till then and during the whole time when there might have been doubts, I had not been willing to give a name to this discovery, but on the return of our boats I christened it Adélie Land. The most prominent cape which we had seen during the morning, at the time we were trying to get nearer to the land, received the name of *Cap de la Découverte*. The point near which the boats landed, and where they were able to collect geological specimens, was called *Pointe Géologie*."*

A tremendous storm arose shortly afterwards, and the ships were in danger, but succeeded in reaching open water. After the storm had ceased, they returned again south, but further west, and on the 29th, nearly off Cape Carr, met the U. S. S. "Porpoise," Commander Ringgold, but owing to a misunderstanding, they did not communicate. On the 30th the French ships sailed for a distance of 20 or 25 leagues, along a wall of ice which was from 30 to 45 meters high. This ice bluff was too elevated to permit the explorers to distinguish the details of the interior. "Thus, for more

* "Voyage au Pôle Sud," etc., Tome Huitième, page 154.

than twelve hours, we had followed this wall of ice which was perfectly vertical on its sides and horizontal on its top. Not an irregularity, not the slightest prominence broke this uniformity during the twenty leagues which were sailed over during the day. As for the nature of this enormous wall, as about the appearance of Adélie Land, opinions were again various; some held that it was a compact mass of ice independent of any land, others, and I share this opinion, contended that this formidable belt was at least an envelope, a crust, to a solid base, either of earth or rocks, or even of high placed shallows spread out around a great land. In this, I always base myself on the principle that no ice of great size can form in the open sea, and that it always needs a solid supporting position to enable it to be fixed in a definite spot. However this may be, at ten o'clock in the evening I started to the southwest, after having christened the ice barrier we had just examined, *Côte Clarie*."* D'Urville stood north from here, and on February 17th reached once more Hobart Town.

D'Urville's cruise is important. His narrative is so lucid that it is unnecessary to comment at length on it. It may be well, however, to call attention to the fact that both Wilkes and D'Urville saw this part of Wilkes Land, and that the narratives and the charts of the two explorers tally in all respects. Wilkes, however, saw even more than did D'Urville, for Wilkes, as his chart shows, went close to the coast between Piner's Bay and Cape Carr.

In 1839 Lieutenant Charles Wilkes, U.S.N.,† commanding the United States Exploring Expedition on a voyage around the world, sailed on February 25th from Orange Harbor, Tierra del Fuego.‡ He was on the gun-brig "Porpoise," with the pilot boat "Sea-Gull," 110 tons, commanded by Lieutenant Johnson, as tender. On March 1st they sighted Ridley Island in the South Shetlands. On the 2d

* "Voyage au Pôle Sud," etc., Tome Huitième, pages 175-177.

† "Narrative of the United States Exploring Expedition," during the years 1838, 1839, 1840, 1841, 1842, by Charles Wilkes, U.S.N., Commander of the Expedition. Philadelphia, Lea & Blanchard, 1845.

‡ "Narrative U. S. E. E.," Vol. I, pages 133-145.

they made O'Brien, Aspland and Bridgeman Islands. On the 3d they sighted Mount Hope, the eastern extremity of Palmer Land, in 63° 25′ south latitude, 57° 55′ west longitude. They also discovered three small islets, which Wilkes christened the Adventure Islets. There were many icebergs floating about and too much ice along the coast to attempt landing. The "Sea-Gull" returned north on March 5th. On the 7th the "Porpoise" was nearly wrecked on some high land, which proved to be Elephant Island. This is of volcanic appearance and its valleys were filled with ice and snow.

On February 25th, also, two other ships of the United States Exploring Expedition sailed from Orange Harbor.* These were the "Peacock," Captain Hudson, and the "Flying Fish," Lieutenant William M. Walker. On March 11th they saw the first iceberg. On the 13th their position was in 64° 27′ south latitude, 84° west longitude. On the 14th Captain Hudson remarked a great and striking change in the weather, as since 62° south latitude it had become much more settled and free from the sudden squalls and constant gales they had experienced after leaving Cape Horn. On the 17th and 18th, however, they had another heavy gale. On the 20th the "Flying Fish" was in 67° 30′ south latitude, 105° west longitude. A cast of the lead showed no bottom in 100 fathoms. The water was much discolored, and Lieutenant Walker afterwards observed this same discoloration of the water in the vicinity of extensive masses of ice; he thought it might possibly be produced by refraction. The "Flying Fish" at this time was in a fog. This lifted and disclosed a wall of ice from 4 to 6 meters high, extending east and west as far as the eye could reach, and spreading out into a vast and seemingly boundless field to the south. Some floating ice had the appearance of being but lately detached from the land. On the 20th the "Peacock" was in 68° south latitude, 90° west longitude, and obtained a sight of an icy barrier of field-ice and icebergs. On the 21st the "Flying Fish" was in 68° 41′ south latitude,

* "Narrative U. S. E. E.," Vol. I, pages 149–161; 405–408; 408–414.

103° 34′ west longitude, running among ice-islands. On the 23d the "Flying Fish" reached 70° south latitude, 100° 16′ west longitude; here they observed an appearance of land,* and saw large masses of ice and numerous icebergs. They then turned northward, and fell in with the "Peacock" on the 25th, in 68° south latitude, 97° 58′ west longitude. The two ships then returned together to Orange Harbor.

[*To be continued.*]

ROTARY TRANSFORMERS:

THEIR HISTORY, THEORY AND CHARACTERISTICS.†

By George W. Colles, A.B., M.E.

(*Continued from p. 282.*)

Pressure Relations.—Considering now the question of terminal pressure as affected by phase relations, this matter has been very fully dealt with mathematically by several electricians, among whom we may mention Professor Ayrton[46] and R. M. Friese.[47] Assuming for simplicity a theoretical sine-distribution over the armature for the magnetic flux—a condition which, however, does not occur in practice—the mode of determining the pressure between any two slip-rings is as follows: Let the sinusoidal curve shown in *Fig. 1* (Plate XVIII) represent the curve of magnetic flux, the abscissas being angular distances on the periphery of the armature and the ordinates the flux density at each point. If the total flux be represented by N and its maximum density by N_m, then the equation of the curve is

$$\Phi = N_m \sin \vartheta,$$

ϑ being any angular distance from the neutral point; and the value of the total flux is

$$N = N_m \int_0^{\pi} \sin \vartheta \, d\vartheta = 2 N_m$$

* The existence of land at this spot was disproved by de Gerlache. See *post.*

† A thesis presented in candidature for the degree of Master of Science, in the Columbian University, May, 1900.

[46] *Jour. I. E. E.*, V. 22, p. 340, April 27, 1893.

[47] *Elektrotech. Zeitsch.*, Feb. 15, 1894.

The electromotive force induced at any point of the armature is proportional to the flux at that point, and is equal to

$$k N_m \sin \vartheta,$$

where k is a constant depending on the speed of rotation and the number of conductors per unit length of periphery; and the E.M.F. for any angular breadth

$$\frac{2\pi}{s}$$

of the armature periphery, where s is the number of phases or armature segments, is

$$k N_s = k N_m \int_a^{a+\frac{2\pi}{s}} \sin \vartheta \, d\vartheta$$

$$= k N_m \left[\cos a - \cos\left(a + \frac{2\pi}{s}\right)\right],$$

a being the angular distance of the rear end of the segment from the neutral point. Reducing this expression further to the simple sinusoidal form, we obtain

$$k N_s = k N_m \left[\left(1 - \cos\frac{2\pi}{s}\right)\cos a + \sin\frac{2\pi}{s}\sin a\right]$$

$$= \sqrt{2 - 2\cos\frac{2\pi}{s}}\; k N_m \cos\left(a - \tan^{-1}\frac{\sin\frac{2\pi}{s}}{1 - \cos\frac{2\pi}{s}}\right)$$

$$= k N \sin\frac{\pi}{s}\cos(a - \beta),$$

where

$$\tan\beta = \frac{\sin\frac{2\pi}{s}}{\operatorname{vers}\frac{2\pi}{s}} = \frac{2\sin\frac{\pi}{s}\cos\frac{\pi}{s}}{2\sin^2\frac{\pi}{s}} = \cot\frac{\pi}{s}$$

We see from this and from *Fig. 2* that this angle β is the complement of $\frac{1}{2}$ the phase-angle, or

$$\frac{\pi}{2} - \frac{\pi}{s};$$

hence

$$k N_a = k N \sin \frac{\pi}{s} \cos \left(a - \frac{\pi}{2} + \frac{\pi}{s}\right)$$

$$= k N \sin \frac{\pi}{s} \sin \left(a + \frac{\pi}{s}\right).$$

This shows that the maxima and minima are where the segment is bisected by the point of maximum flux density and the neutral line, respectively.

The maximum E.M.F. is

$$k N \sin \frac{\pi}{s},$$

and the virtual is accordingly, on well-known principles,

$$\frac{k N}{\sqrt{2}} \sin \frac{\pi}{s};$$

and as the direct-current E.M.F. is, by the common formula, $k N$, the ratios of the maximum and virtual alternating E.M.F. to the latter are thus simply

$$\sin \frac{\pi}{s} \text{ and } \frac{1}{\sqrt{2}} \sin \frac{\pi}{s},$$

respectively.

We obtain thus the following pressure ratios for different values of s:

Number of segments or slip rings $= s$.	Ratio of $A\,C$ to $D\,C$ pressure.	
	Maximum $= \sin \frac{\pi}{s}$	Virtual $= \frac{1}{\sqrt{2}} \sin \frac{\pi}{s}$
2 (monophase)	1	$\frac{1}{\sqrt{2}} = .7071$
3	$\frac{\sqrt{3}}{2} = .866$	$\frac{\sqrt{3}}{2\sqrt{2}} = .6123$
4	$\frac{\sqrt{2}}{2} = .707$	$\frac{1}{2} = .5$
6	$\frac{1}{2} = .5$	$\frac{\sqrt{2}}{4} = .3535$
8	$\frac{\sqrt{2-\sqrt{2}}}{2} = .383$	$\frac{1}{2}\sqrt{1-\frac{\sqrt{2}}{2}} = .2706$

For opposite armature connections we have, of course, in all cases the same pressure ratio as in the first of the above instances.

We may also show these pressure relations graphically to the eye, as in *Fig. 3*, which we may suppose to represent the armature in outline. The arcs $A\,2$, $A\,3$, $A\,4$, etc., are the phase-angles

$$\frac{2\pi}{s}$$

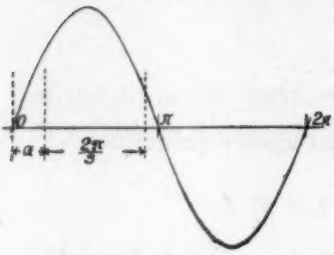


Fig. 1.

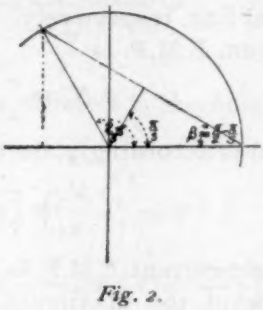


Fig. 2.

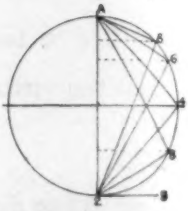


Fig. 3.

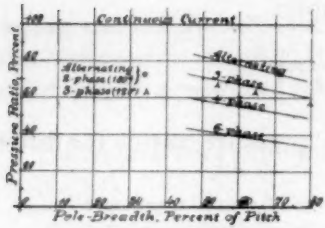


Fig. 5.

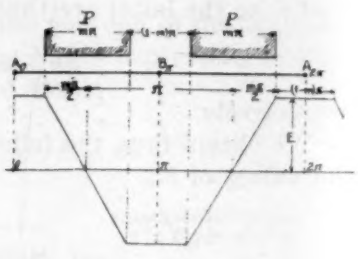


Fig. 4.

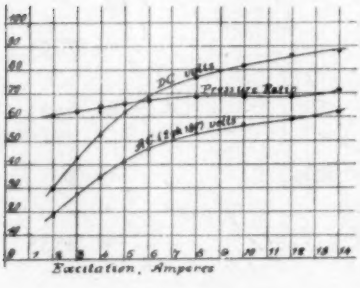


Fig. 6.

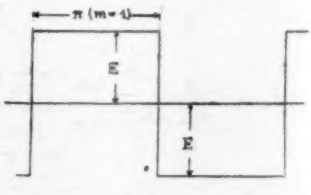


Fig. 7.

PLATE XVIII.—Pressure relations in the single-coil transformer.

for the different connections; the angles $A\,2B$, $A\,23$, $A\,24$, etc., are then equal to one-half the phase-angles or to

$$\frac{\pi}{s},$$

and the chords A 2, A 3, etc., are in the ratio of the sines of those angles. Hence we see that the maximum pressure obtained for any given angular span of the armature is proportional to the chord of that angle. This is also evident from the consideration that the amount of magnetic flux cut by any segment is proportional to its projection on the neutral line, owing to the assumed even distribution of the flux across that line.

This is the voltage relation on theoretical assumptions; but these are not realized in practice. Routin[48] and Kapp[49] have worked out the voltages on the assumption of equal distribution of the magnetic flux over the surface of the pole-pieces, and assuming different breadths of pole-face. This assumption gives us an irregular flat-topped curve of electromotive force formed of broken straight lines, whose minor characteristics vary according as the breadth of pole-face is greater or less than 90 electrical degrees, and according to the width of armature segment, and whose maximum ordinate is of course equal to the direct current E.M.F., but the square root of the mean square of an ordinate, which measures the virtual alternating volts, varies with the shape of the curve, increasing as the pole-piece is narrowed, and the flat portion of the curve, hence also its area, becomes greater. This case is worked out for a 180° phase-angle (alternating current) in *Fig. 4*, where $P\,P$ represent the pole-pieces, supposed to be of a breadth m, and the line $A\,B\,A$ immediately beneath, the armature developed. The abscissas of the curve are taken opposite the position of the point A; the slip-rings being supposed connected at $A\,B$. Let E be the direct current pressure and e_v the virtual alternating pressure; then we have

$$\pi\, e_v^2 = \frac{8\,E^2}{m^2\,\pi^2} \int_0^{\frac{m\,\pi}{2}} x^2\, d\,x + E^2 \int_{\frac{m\,\pi}{2}}^{\pi - \frac{m\,\pi}{2}} d\,x$$

$$= \frac{m\,\pi\,E^2}{3} + \pi\,E^2\,(1 - m)$$

[48] *L'Eclairage Elec.*, V. 11, p. 531, June 12, 1897.
[49] *Elektrotech. Zeitsch.*, V. 19, p. 621, Sept. 15, 1898.

whence

$$e_v = E\sqrt{1 - \frac{2m}{3}}$$

whence we see that

For $m = \frac{3}{4}$, $\quad e_v = \frac{E}{\sqrt{2}} = .707\,E$

For $m = \frac{2}{3}$, $\quad e_v = \frac{\sqrt{5}}{3}E = .745\,E$

For $m = \frac{1}{2}$, $\quad e_v = \sqrt{\frac{2}{3}}E = .816\,E$

From this we see that when the pole-piece has a breadth equal to three-fourths of the pitch, the pressure ratio will be the same as with the sinusoidal distribution, and for breadths less than this, the alternating pressure, that is to say, the *ratio of conversion*, is raised; and by diminishing the former to one-half the pitch, we may raise the latter by as much as 15 per cent.

In a similar manner Kapp deduces the following values:

Voltage for	Sine Law.	Pole-breadth ⅔.	Pole-breadth ½.
Continuous Current	100	100	100
Alternating Current	70·7	75	82
Three-phase	61·2	65	71
Four-phase	50	53	58
Six-phase	35·4	37	42

The assumption of uniform flux-distribution over the pole-faces is doubtless nearer to actual practice than the sine-law; still it does not appear to exactly represent the actual distribution, which is in general something between the two assumptions, slightly intensified at the center and fringing out at the edges. Thus, a 55-kilowatt three-phaser described by Thompson,[50] whose pole-breadth was 54 per cent. of the pitch, had a ratio of conversion of only 66·6 per cent., which shows less average concentration of the field than is required by the above table. The same machine had had originally a pole-breadth of 80 per cent., which gave a conversion ratio 57·7 per cent. In another case, a 600-kilowatt four-phase machine, the pole-breadth was 72 per cent., and

[50] *Jour. Inst. E. E.*, V. 27, p. 680, Nov. 10, 1898.

the conversion ratio 71·8 per cent., which corresponds exactly with the tabular value.[51] In some three-phase 200-kilowatt machines, now in Brooklyn, N. Y., the pole-breadth was 64·7, the conversion ratio 63·3 per cent.—here again somewhat below the tabular value. These empirical values, along with curves plotted from Kapp's table, are plotted in *Fig. 5*.

Pole-breadth is not, however, the only thing that affects the conversion ratio, as seen by the curve in *Fig. 6*, which is plotted from values given by Thompson in the article referred to, for a converter running with a *continuous current primary* and two-phase secondary at the constant speed of 1,200 revolutions per minute, and different excitations. In this case the pressure ratio rose from 60·8 per cent. to 71·0 per cent. during the excitation of the field, a variation of 16·6 per cent.

It is easy to see that such a rise would be due on account of armature reactions, which would, on account of excessive current-lag, be proportionately larger at feeble excitations, and thus tend to scatter the field. Such reactions have also an important effect in another direction, which will be pointed out under the head of Hunting; in both cases the remedy is to strengthen or "stiffen" the field. The dephasement of the impressed and counter-electromotive forces would also cause an apparent rise in the conversion ratio.

A remarkable example of an effect of the opposite character, of reactions upon the conversion ratio, is also given by Thompson in the same article. In this case a four-pole 55-kilowatt three-phase transformer—the same as that already referred to, page 46—ran synchronously without any excitation, but with a large backward lead of the secondary brushes, taking in three currents of 155 virtual ampères at 100 virtual volts and giving out 46 continuous current ampères at the *same voltage!* Needless to say, we cannot fully

[51] This machine is put down by Professor Thompson as a three-phaser, which appears to be certainly an error (*Ibid.*, p. 710). There is nothing to account for such a high pressure ratio, in a three-phase machine, whereas all the other cases show values below the tabular value.

analyze this case, at least without full data, but we may point out the following considerations:

(1) As the *D C* pressure of the machine with its normal field was 300 volts at 370 revolutions per minute, in this case (at 627 revolutions per minute) it would have been 400 volts, and the induced field-strength was therefore only one-fourth the normal.

(2) The discrepancy between the ampères on the two sides of the machine shows the primary current to have been nearly all wattless.

(3) Owing to the weak field there was a *lag* in the primary current, and this lag was practically 90°.

(4) This 90° lag, with its accompanying enormous wattless current, induced in the pole-pieces a field of considerable strength, and with a minimum of lateral distortion.

(5) In like manner the large backward lead of the secondary brushes reacted to produce and maintain a constant field in the pole-pieces, also with little lateral distortion, and the two slight distortions neutralized each other.

(6) The primary and secondary circuits thus combined to produce a concentrated field, though weak.

(7) *Theoretically*, the only way in which the primary could be raised to equality with the secondary pressure would be to expand the tops of the curve of *Fig. 4* to one-half the circumference, the sloping sides becoming vertical, so that the curve takes the form shown in *Fig. 7;* in other words, the flux is concentrated in a mere point.

(8) While of course this could not happen in practice, such concentration may be accountable for a large part of the rise, while armature losses and dephasement of the impressed and counter-electromotive forces would easily make up the difference.

(9) We might otherwise or additionally account for the excess primary virtual pressure by the presence of harmonics such as, for instance, a large tertiary harmonic, causing the curve to assume a double-peaked or crater-like form.[52]

[52] As shown, for instance, by Steinmetz, Discussion on "Alternating Current Curves," *Figs. 3* and *4*, *Trans. A. I. E. E.*, V. 12, pp. 476–477, June 27, 1895.

In connection with this machine it is worth while to remark further, as indicative of the very great flexibility of the system, that it would, according to Thompson, "run as a synchronous motor delivering continuous current sparklessly, *with or without* excitation of the field-magnet, and with brushes set at zero, or set with either a large forward or large backward lead."

Pressure Adjustment.—One of the disadvantages of the one-coil transformer, for any number of phases, is that it transforms up instead of down, and, in addition, gives us uneven and awkward ratios. We are, however, by the means indicated above, page 45, enabled to adjust the relation within certain narrow limits. Thus, by properly shaping the pole-pieces we obtain for an alternating current ratio or two-phase with 180° phase-angle (to follow the selected terminology) the simple ratio $\frac{3}{4}$ or $\frac{4}{5}$, instead of ·707, as required by the sine law; and similarly we may bring the ratio ·612 of the three-phase connection up to $\frac{2}{3}$. This change was, in fact, made in the 55-kilowatt machine just spoken of, which originally had spreading pole-faces covering an arc of 72° on a 90° pitch, so that the pole-breadth was 80 per cent. Under these circumstances the conversion ratio was only 57·7 per cent., so that with a 300-volt secondary pressure, the primary pressure was only 173 volts. By cutting away the pole horns, however, until the pole-breadth was but 54 per cent. of the pitch, the conversion ratio was raised to 66·6 per cent., and the secondary pressure to an even 200 volts.

This method is, however, as will be observed, of very limited application. Another, admitting of more flexibility, was first described in Blackburn and Spence's English patent of 1895,[53] and subsequently by Heldt in this country.[54] It consists, briefly, in winding additional coils upon the armature between the points of connection with the closed coil winding and the slip-rings. This lengthens the *A C* or polyphase turns, and hence increases the *A C* or polyphase pres-

[53] No. 11,153.

[54] *Elec. World*, V. 28, p. 68, July 18, 1896.

sure, without affecting that in the *D C* circuit. In a monophase circuit such a coil need be interposed on only one side of the closed coil winding; in polyphase circuits one such coil is interposed for each slip-ring connection. The additional windings thus added are necessarily of the open coil or star type, as shown in the Van Depoele patent described above (Plate XVI). This winding, as adapted to a three-phase rotary, is substantially shown in *Fig. 3* of Plate XIX. The whole amounts to a star and mesh winding. In this manner the conversion ratio may be brought up to any desired figure. Apparently even very high pressures, as those direct from the transmission line, without any intermediary stationary transformers, might be used on such a machine properly wound; but Mr. Heldt prefers only to bring the alternating or polyphase pressure up to equality with the *D C* pressure. It is to be observed in this connection that this feature really introduces the elements of a two-coil transformer, because no direct current, or secondary current, passes through the star or auxiliary winding; on the other hand, the primary alternating or polyphase current is no longer sufficient to neutralize the other in its heating effects in the mesh or main winding, to the full extent possible in the simple rotary. With a high voltage ratio, in fact, practically the whole advantage of the one-coil transformer, which is based on such current neutralization, would be lost, and we might as well build the machine with the coils entirely separate, and so get the added advantage of more perfect protection from high-pressure leaks. Still, the device is undoubtedly an ingenious and highly useful one, furnishing, as it does, the only general solution of the problem of pressure transformation in a one-coil transformer that we have.

Shifting the brushes as a means of altering slightly the conversion ratio may prove useful as a temporary expedient in some cases, for, as we have already seen, the same difficulty as regards sparking is not inherent in the rotary transformer as is the case with nearly all other forms of direct-current machinery. But the same cause which prevents sparking, to wit, the automatic self-adjustment of the alter-

nating lag or lead and its reaction upon the field, *ipso facto* preserves or tends to preserve the conversion ratio constant; so that we cannot hope, in general, to accomplish very much by this plan. In the unusual case mentioned on page 47, the *A C* pressure was in this way brought up to virtual equality with the *D C*, as we have seen.

Other modes of varying the conversion ratio will be treated under the head of

Pressure Regulation.—The question of pressure regulation for variations of load in a rotary transformer is one of great importance; though not more so, perhaps, than in a stationary transformer, and probably easier of a satisfactory solution. Yet it cannot be said that a satisfactory solution has as yet been reached. The case here is much the same in character as that already treated in the similar case of dynamotors (page 16). A number of devices have been invented for this purpose, differing according as the machine was used as an alternating-direct or direct-alternating current transformer.

As already stated on page 228,* the alteration of the field excitation in a dynamotor produces no effect on its conversion ratio, and neither does it affect the armature losses for a given load on the machine. Not so the latter, however, with the rotary transformer, for here we encounter one of those peculiarities of alternating currents which place this machine on a different footing from the dynamotor. Although we do not, in the rotary transformer case, affect the real pressure ratio, we do affect the virtual or *apparent* pressure ratio indirectly, by increasing or diminishing the armature losses. In fact, as we shall hereafter point out, the latter are increased or diminished according as the armature current is thrown out of or brought into phase with the pressure in the primary supply mains. Now, as heretofore shown (page 279†), in order to cause the current to lead or lag behind the E.M.F. in the supply mains, we have only to give the machine a greater or less degree of excitation than that sufficient to generate an equal counter-

*March number of this *Journal*.

†April number of this *Journal*.

E.M.F. Hence, any device which will cause the current to lead or lag behind the E.M.F. in the supply mains during light loads, so as to cause a relatively large armature loss, and bring it into phase there with as the load is thrown on, will thereby equalize the armature losses for all loads and so render the pressure at the *D C* terminals constant. A device for this purpose has been patented to Steinmetz,[55] and consists in a field rheostat combined with a solenoid or other governor adjusted to strengthen the fields as the load increases, thus bringing the current more nearly into phase and decreasing the field-losses—the machine being run at no load with deficient excitation and consequent lagging current.

We see, therefore, that while the real conversion ratio or a rotary transformer remains the same under any excitation—neglecting for the moment the effect of armature reactions—its *apparent* conversion ratio is affected by changes in excitation, due to the consequent differences of phase between the impressed and counter-electromotive forces. But increasing the field-strength will not, as in a continuous current machine, increase the apparent primary voltage indefinitely, but only until the impressed and counter-electromotive forces have come into phase; after which the ratio diminishes again. A simpler and obvious mode of effecting the same thing is merely to compound or wholly wind the machine with a series field-coil from the secondary circuit.

It has been also suggested that transformers be made with a large magnetic leakage, so that the machine, being overexcited at no load, causing the current to lead, a greater alteration of the angle of lead will be occasioned on throwing on the load. Such leaky transformers have been made with an apparent conversion ratio which could be made to vary to the extent of 1 : 2, but it has been stated by their author[56] that they have no *regulating* qualities at all.

---

[55] No. 543,907, of August 6, 1895.

[56] W. M. Mordey, in discussion of Thompson's paper, *loc. cit.*, pp. 699 and 711.

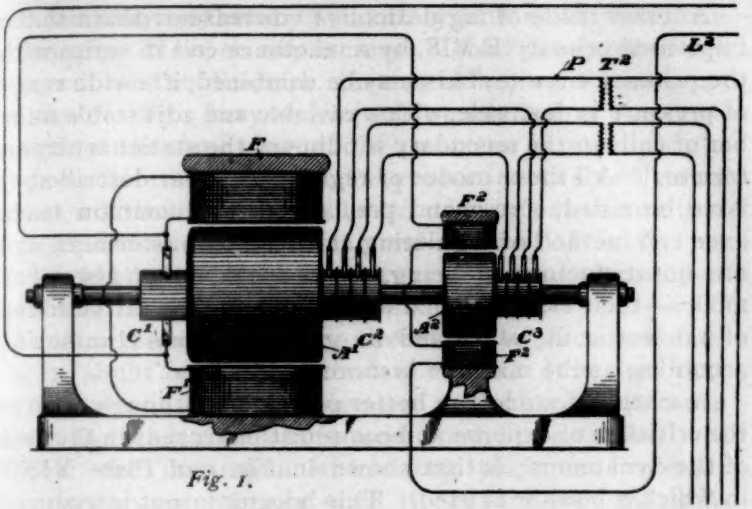


Fig. 1.

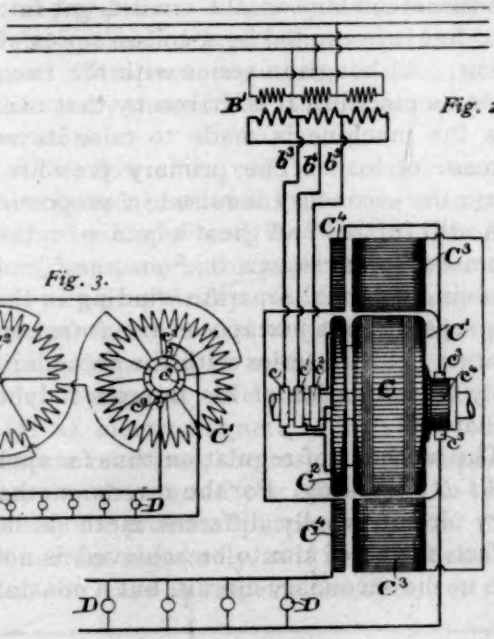


Fig. 2.

Fig. 3.

PLATE XIX.—Pressure regulation. *Fig. 1*, Scott's method (1894). *Figs. 2* and *3*, Thomson's method (1896).

Another mode of regulation is to increase or diminish the impressed primary E.M.F. by a reactance coil in series with the primary circuit. This may be combined, if a wide range of pressure is desirable, with a variable and adjustable number of coils in the secondary winding of the stationary transformer.[57] All these modes of regulation so far described, it is to be noted, correspond precisely to the common reactance coil method of regulating stationary transformers, and are unsatisfactory in being, so to speak, only "negative" modes—their essential characteristic being the introduction of a defect at the start, and its greater or less elimination according as the machine is more or less used.

A method founded on better principles, although open to the criticism of expense and complication (just as in the case of the dynamotor), is that shown in *Fig. 1* of Plate XIX,[58] in which a booster is used. This booster is not introduced into the secondary or *D C* circuit, but into the primary circuit; but it is excited by a coil in series with the secondary circuit. Although in series with the two-phase primary of the main machine, it is driven by that machine as a motor; thus the machine is made to raise its own pressure with increase of load. The primary pressure being raised, of course the secondary is raised in proportion.

A still further and great advance on the foregoing is the Thomson[59] plan, shown in *Figs. 2 and 3* of the same plate, involving a partial separate winding in the primary circuit, on a separate but juxtaposed armature core, and excited by separate fields in series with the secondary circuit. This is really an adaptation of his improved dynamotor as shown in Plate XI.

The methods of regulation thus far spoken of are limited to *A C-D C* working. For the reverse method, with a *D C* primary circuit, wholly different methods may be employed. In fact, the chief aim to be achieved is not a constant pressure in the secondary circuit, but a constant speed, because

[57] As shown by Lamme's patent, No. 606,560, of June 28, 1898.
[58] Scott's patent, No. 515,885, of March 6, 1894.
[59] Patent No. 563,895, of July 14, 1896.

the motors driven thereby will run synchronously with the transformer. Now, on any increase of load the speed of the latter will tend to diminish, just as in any continuous-current motor. This may be avoided by weakening the field-strength at the same time, and if an exciter is mechanically driven by the transformer and at proportionate speed therewith, it will diminish the field excitation on any diminution in speed, and so accomplish the end in view.[60] It is obvious that by this method the secondary pressure must be subject to wide variations.

Another mode by the same inventor is to place reactance coils in shunt with the secondary circuit. It is clear that this is open to the same objections as the use of reactance coils in the other cases above mentioned, but *a fortiori.*

From the discussion which took place on Professor Thompson's paper already cited, it appears that the difficulty of securing good regulation—taken with the tendency to hunt, which will be spoken of later—is the prime factor which has caused European engineers to look with dissatisfaction on the rotary transformer, and its place to be taken by motor-generators.

Current Relations.—The flow of current in a rotary transformer has been investigated mathematically by a number of writers, in particular by Kapp[61] and by Woodbridge and Child,[62] and Professor Thompson in the paper above referred to has treated the subject graphically. A detailed exposition of the mathematical theory would be beyond the scope of this paper, but the main principles will be given.

The easiest mode of treating the subject is that of superposition. So far as electromagnetic effects are concerned, such as armature reactions, the result of superposition is nearly the same as the sum of the effects of the two currents, so that we may for practical purposes consider the reactions upon each current separately, as if it were the only one in the field. But the case as respects the ohmic or re-

[60] Lamme's patent, No. 606,015, of June 21, 1898.
[61] *Elektrotech. Zeitsch.*, V. 19, p. 621, Sept. 15, 1898.
[62] *Elec. World*, V. 31, p. 12, Jan. 1, 1898.

sistance effect stands differently, for, as is easily seen, the resistance to two opposite currents flowing in a conductor is that of their difference and not the sum of their joint resistances. We need, therefore, to find what this resultant value is for each conductor in the armature, and for each position of that conductor.

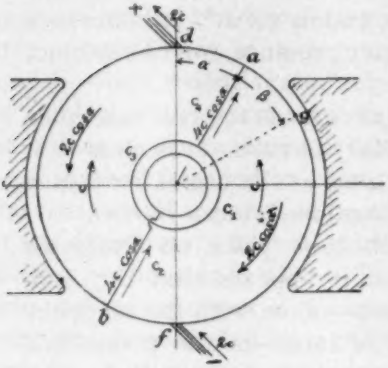


Fig. 1.

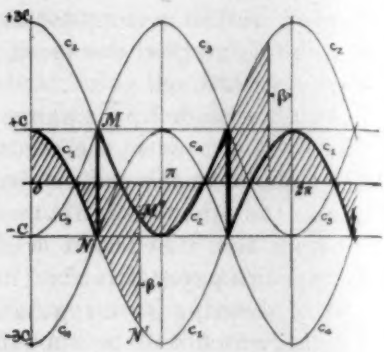


Fig. 2.

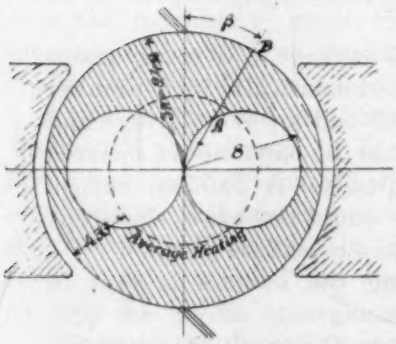


Fig. 3.

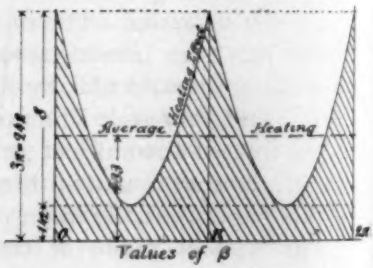


Fig. 4.

PLATE XX.—Armature currents and heating in the single-coil transformer.

Taking first the simplest case—that of a two-segment (monophase) armature, having a sinusoidal current wave, no phase-displacement, and 100 per cent. efficiency; if E is the DC E.M.F. and $2C$ the DC current, the output of the machine is $2CE$. The maximum pressure on the alternating side being also E, the maximum current on that side is

4 C, so that the output on this side, which is one-half their product, may also be equal to 2 CE, the output of the DC side. This maximum current on the AC side occurs when the armature is in the position of maximum pressure on that side—that is, when the line of ring-connections is in the position df (see Plate XX, *Fig. 1*). At this moment, then, a net current equal to $2C - C = C$ is passing downwardly through both halves of the armature, supposing the DC to be the generator side, and the upper brush positive, as shown. Now, when the armature has passed through an angle a and the line of ring-connections is in the position ab, the alternating currents in each half will be $2C \cos a$, and each vertical half of the armature will be divided into two parts by the line ab, so that we have for the net current in each of the four parts,

$$\begin{aligned}
&\text{in } da, && c_1 = -C(1 - 2\cos a),\\
&\text{in } af, && c_2 = +C(1 + 2\cos a),\\
&\text{in } fb, && c_3 = +C(1 - 2\cos a),\\
&\text{in } bd, && c_4 = -C(1 + 2\cos a).
\end{aligned}$$

These curves are plotted in *Fig. 2*. The current in any individual conductor g making an angle β with the division line ab, and an angle $a + \beta$ with the commutation line, will therefore be, for any value of a,

$$\begin{aligned}
&\text{from } O \text{ to } \pi - \beta, && c_1 = C(2\cos a - 1),\\
&\text{from } \pi - \beta \text{ to } \pi, && c_2 = C(2\cos a + 1),\\
&\text{from } \pi \text{ to } 2\pi - \beta, && c_2 = C(2\cos a + 1),\\
&\text{from } 2\pi - \beta \text{ to } 2\pi, && c_1 = C(2\cos a - 1).
\end{aligned}$$

In one-half revolution the total work lost is

$$\begin{aligned}
w &= r\Big(\int_0^{\pi-\beta} c_1^2\,dt + \int_{\pi-\beta}^{\pi} c_2^2\,dt\\
&\qquad + \int_{\pi}^{2\pi-\beta} c_2^2\,dt + \int_{2\pi-\beta}^{2\pi} c_1^2\,dt\Big)\\
&= \frac{C^2 r}{2\pi n}\Big(\int_{2\pi-\beta}^{\pi-\beta}(1 - 2\cos a)^2\,da\\
&\qquad + \int_{\pi-\beta}^{2\pi-\beta}(1 + 2\cos a)^2\,da\Big),
\end{aligned}$$

remembering that $da = 2\pi n\, dt$, if n is the number of revolutions per second. Continuing the reduction,

$$w = \frac{C^2 r}{2\pi n}\left[\int_0^{2\pi}(1 + 4\cos^2 a)\, da + 4\left(\int_{\pi-\beta}^{2\pi-\beta} \cos a\, da - \int_{-\beta}^{\pi-\beta} \cos a\, da\right)\right]$$

$$= \frac{C^2 r}{\pi n}(3\pi - 8 \sin \beta).$$

This equation is exhibited to the eye in *Figs. 3* and *4*.

This is the work or heating effect for one conductor only, or per unit length of the armature periphery, according to the meaning we give to r. To find the whole work we integrate this equation for the whole circumference, or, as β is limited to values between 0 and π, we have for one revolution of the armature,

$$W = 2\int_0^{\pi} w\, d\beta$$

$$= 2\frac{C^2 r}{\pi n}\int_0^{\pi}(3\pi - 8 \sin\beta)\, d\beta$$

$$= 2\frac{C^2 r}{\pi n}(3\pi^2 - 16)$$

$$= 8{\cdot}664\ \frac{C^2 r}{n}.$$

The power consumed, at n revolutions per minute, is

$$P = \frac{2C^2 r}{\pi}(3\pi^2 - 16) = 8{\cdot}664\, C^2 r.^{63}$$

The average heating per unit periphery is

$$\frac{W}{2\pi} = 4{\cdot}332\ \frac{C^2 r}{\pi n},$$

---

[63] This value is the same as that given by Kapp, but the mode of reaching it is not quite the same. There are two advantages of the method given above: first, it is simpler, although involving a double integration; and, second, it gives the heating in each part of the armature, which Kapp does not consider at all, but which is a matter of great importance, because we cannot properly average up our heating all over the armature, and then make the average equal to that allowed in an ordinary dynamo, when some of the coils are heated more than twice that average.

and it is plotted in *Figs. 3* and *4* on the same scale as w $\left(\frac{C^2 r}{\pi n} = 1\right)$.

We now pause to consider briefly some of these results.

From *Fig. 2* we see that the current in an individual coil changes abruptly at the brushes by an amount $2C$, and that it either rises to its highest value just before reaching the brushes (as shown by the shaded area in *Fig. 2*, for which $\beta = 30°$), when it abruptly falls, or else is suddenly raised at that point and falls off gradually, depending on whether β is less or greater than 90°. For all values of β between $\beta = 60°$ and $\beta = 120°$, the current has four zero points, independently of reversal at the brushes, during a revolution; for other values, only two such points. The value $\beta = 90°$ is shown by the heavy line. We can see in a general way that the area of the curve (and hence the heating effect) increases from $\beta = 90°$ in both directions, since the change is accomplished by simply moving the line $M\ N$ along the curve (as for instance, to M′ N′ for $\beta = 30°$).

Fig. 3 shows the meaning of the equation for w on page 358. The circle forming the outline of the armature is drawn equal to 3π on a scale of

$$\frac{C^2 r}{\pi n} = 1,$$

to represent the first term of w, and within this are inscribed two circles of diameter 8 each. It will be clear that the portion $A\ B$ of any radius will represent the corresponding average heating of a coil making the corresponding angle β with the line of slip-ring connections $a\ b$, *Fig. 1*. The dotted circle shows the average heating of all the coils, which is the distance between the circumference of this circle and the outer one.

The same thing is plotted rectilinearly in *Fig. 4*. From these figures and the equation for w, we see that the maximum heating occurs in the coils or conductors lying adjacent to the slip-ring line, and that this heating is equal to

$$3\,\frac{C^2 r}{n},$$

or about 6·62 times that of the coils in quadrature with it, and 2·18 times the average for the whole armature.

For other distributions of the magnetic field, to wit, with pole-breadths equal to $\frac{2}{3}$ and $\frac{1}{3}$ the pole-pitch, and a uniformly distributed magnetic flux, Kapp finds the heating to be only 92 and 78 per cent., respectively, of the heating with sinusoidal wave. This shows a distinct advantage of concentrating the field, as might in fact be inferred from the rise in *A C* pressure which accompanies it.

The investigation of the three-phase and four-phase connections follows the same general method, and we need not pursue it in detail. It will suffice to state the results arrived at by Kapp:—

ARMATURE HEATING ($\div C^2 r$), FOR CONSTANT OUTPUT.

	Sine-law.	Pole-width ⅔.	Pole-width ⅓.
Monophase	8·66	7·97	6·79
Three-phase	—	3·28	3·02
Four-phase	2·55	2·24	2·20

As might be expected from the fact that the energy supplied from a monophase circuit is intermittent, while that from a polyphase circuit is constant, the armature heating is more than cut in two by a three-phase connection, and a further large reduction is shown by a four-phase connection. As the E.M.F. reaches its maximum at three points of a revolution in the one case, and at four in the other, there is less chance for a large fluctuation in the current. The virtual current is besides, of course, much less in proportion as the phases are multiplied, as shown by the following table, deduced from that on page 41 on the assumption of 100 per cent. efficiency:

Number of Segments.	Armature Current in Each Segment. Maximum.	Virtual.
Continuous	50	50
2 (monophase)	100	70·7
3	77·0	54·5
4	70·7	50·
6	66·7	47·2

Kapp further investigates the case of phase-displacement, which of course increases the current, but only, as he finds, in proportion as it alters the distribution of the flux.

The effect of a leading or lagging current is the same, and is very noticeable if it exceeds a small angle. Some values are given below under "Output."

The above mode of investigation, however, is imperfect, as it takes no account of armature losses, which ordinarily take up 5 to 10 per cent. of the power, and play a necessary part in all machines,—together with the effects of inductance and field reaction which they imply, and which are not neutralized by any current on the *D C* side.

Output.—The proportionate output of a rotary transformer to that of a *D C* dynamo is easily found from the above figures for armature heating. Assuming an even average heating for all the armature coils (which, however, as we have seen, is in single-phase machines very far from being the case), we may adopt as a measure of output an equal heating of the armature. Now the heat lost in a *D C* dynamo, whose current is $2\ C_1$, is $2\pi C_1^2 r$, and from the equation for P (page 58) we therefore have for the output of a monophase rotary transformer:

$$O = \frac{C}{C_1} = \sqrt{\frac{\pi^2}{3\pi^2 - 16}} = \cdot 85$$

In the same way Kapp gets for pole-breadths $m = \frac{2}{3}$ and $m = \frac{1}{2}$ the pitch the outputs ·88 and ·95 respectively, showing how great is the effect on the output of concentrating the flux. Treating the polyphase machines the same way, we get the following table of outputs, in percentages of the same machine considered as a *D C* generator and rotated by mechanical means:

	Sine-law.	Pole-breadth $m = \frac{2}{3}$.	Pole-breadth $m = \frac{1}{2}$.
Monophase	85	88	95
Three-phase	134	138	144
Four-phase	164	167	170
Six-phase	196	198	199

For $\cos \varphi = \cdot 9$ we get for a monophase machine in the last two cases 81 and 88 respectively; that is, the output of the machine is diminished by this amount of phase-lag to the extent of 8 per cent.

We see from the above table that, while the output of a monophase rotary transformer is 5 to 15 per cent. less,

that of a three-phase machine is 34 to 44 per cent. greater than that of the same machine mechanically driven; while the four-phase machine practically doubles the output of the monophase, and the six-phase that of the *D C* dynamo. We see here the great advantage, already referred to on page 281,* of doubling or otherwise increasing where possible the number of phases, and it has for this reason even been suggested [64] that the polyphase generator of the future will have as many armature coils as a continuous current machine, and that the line will be a cable composed of many insulated wires, each communicating with a separate armature segment on a rotary transformer at the delivery end. Unfortunately this arrangement would necessitate either an inordinate number of slip-rings or the awkwardness of rotating brushes, and the feasibility of keeping a large number of line-wires insulated from each other at high pressure seems at least doubtful. Some recent machines of the inductorium type, however, to be spoken of later on, actually proceed upon this principle.

It should not be forgotten that from these figures should be deducted a very considerable percentage to allow for armature losses, which have not been taken into account. Attention is also called to the fact, pointed out by Prof. Carus-Wilson,[65] that the limiting load of a rotary transformer depends not simply on the safe limit of heating which may be allowed, but on the load at which the machine will fall out of step. This, too, depends on the heat-loss in the armature.

In an actual case,[66] it was found that a machine connected up for both monophase and three-phase currents gave an output 1·7 to 1·8 greater in the latter case than in the former.

Efficiencies.—Under this head will be given some actual results, as theory does not appear to have reached that per-

---

* April number of this *Journal*.

[64] *Electrician* (London), V. 42, p. 229, Dec. 9, 1898.

[65] Discussion of Thompson's article, *Jour. I. E. E.*, V. 27, p. 713, Nov. 24, 1898.

[66] *Ibid.*, p. 717.

fection in treating the rotary transformer that it has in treating the dynamo—as may be surmised from the imperfect method adopted in finding heating effects.

The following table has been compiled from data given either by Thompson, in the paper already referred to, or by others during the discussion of that paper; except the last, which relates to the transformers of the Pittsburgh Reduction Company, of Niagara Falls, and is given by Emmet:[67]

Maker.	Authority.	Size, K. W.	Phases.	Frequency.	Efficiency, p. c.
—	Thomas	—	Alt'g	—	75
—	"	—	3	—	92
General Elec. Co.	Thompson	900	3	25	(93-95)
Elec. Const'n Co.	Mance	45	3	42	90
(Dublin R'ys.)	Hobart	200	—	30	91-92[68]
—	"	—	—	—	90[68]
—	Parshall	500	—	—	95
Brown, Boveri & Co.	Thompson	30	4	40	90
Alioth Co.	"	100	4	45	90
General Elec. Co.	Emmet	400	4	25	94

No. 3 gives only the efficiency stated in the manufacturers' guarantee, so that it may be practically disregarded. Nos. 5 and 6 include the stationary transformer, so that the efficiency of the rotary alone would be several per cent. higher in these cases.

The above results cannot be considered more than provisional, as we have no exact information as to how they were obtained. We see merely in a general way that the efficiency of a polyphase rotary transformer, by these figures, varies from 90 to 95 per cent. In practice we may doubtless be more nearly correct in discounting them to some extent.

The one test given for an *A C* transformer shows, what might be expected from the facts brought out under "Current Relations" and "Output" (pages 360 and 361), that its efficiency is much less than that even of a three-phase trans-

[67] *Trans. A. I. E. E.*, Vol. 12, p. 483, June 28, 1895.
[68] Including stationary transformers.

former. But between three-phase and four-phase machines we cannot find any appreciable difference.

As we must generally compound with these figures the loss in stationary transformers, we should probably get as a result but about 85 per cent. efficiency in the general case —little higher than that of a motor-generator. This cannot be called a satisfactory efficiency for what is in effect a single (though not a simple) transformation. As little more can be expected of the one-coil machine than we can now get from it, this may be taken as pointing us in another direction.

Regarding costs, according to Hobart,[69] taking the cost of a motor-generator at 100, we may consider the rotary transformer to cost, including stationary transformers, about 70 to 90 per cent., according to the efficiency expected of them, so that some saving is made by using the transformer, though less than we should reasonably have expected. The repair-bill will also be less, of course, for the transformer.

To sum up, where good regulation on a very variable loading is required, as in lighting service, the diminished cost of the transformer will probably not offset the better regulating qualities of the motor-generator.

Hunting.[70]—There is one disease which appears to be common to all machines which use alternating or polyphase current, and run on the synchronous principle, and that is hunting. So much has been said on this subject that no treatment of rotary transformers, however brief, would be complete without some mention of it. What has been said and done, however, has been more in the line of opinion, experience and experiment than of actual or theoretical investigation. The rotary transformer appears to be particularly liable to this affection, and the subject comes

---

[69] *Jour. I. E. E.*, V. 27, p. 708, Nov. 24, 1898.

[70] There are at least five synonyms for this word which appear to be used indiscriminately—*surging*, *seesawing*, *racing*, *pumping* and *drifting*. I really cannot see why the art requires six words which mean all the same thing. Perhaps the first two most appropriately express the phenomenon, but I have selected "hunting" as being the term in most common use.

up for its share of discussion wherever the rotary transformer is discussed. In fact, hunting in its ordinary form, meaning a swaying or fluctuation of the speed from one extreme to another, with accompanying fluctuation in the secondary pressure, and frequently violent sparking at the brushes, has been found so serious a defect in some cases as to necessitate the replacement of the offending machine by a motor-generator. This was the case in Professor Mengarini's Tivoli-Rome installation.[71] (These machines were, however, two-coil single-phase rotaries.) The defect appears to be particularly prominent in the larger size transformers, and especially where run in parallel. Another puzzling case, according to Professor Thompson, is "when two converters are arranged at the two ends of a long three-phase line for the purpose of feeding continuous currents from one point to another."

The causes of hunting are not in all cases to be ascertained with certainty. A case is related[72] where two transformers could not be induced to run in parallel satisfactorily and to equalize the load, and "the whole trouble was found to lie eventually with the brushes and the unequal resistance they offered at their rubbing surfaces." Still the causes ascribed may be in general grouped under four heads, viz.:

(1) Uneven speed of the steam-engine or other prime mover.

(2) Weak or yielding fields and the consequent armature reactions.

(3) Dissimilarity of the E.M.F. curves of the different machines.

(4) Too much self-induction.

If the fault lies in the steam engine at the distant end of the line, of course the only proper remedy is to correct it at that point. Fluctuating speed of the prime mover will invariably produce its equivalent all over the distribution system.

---

[71] See discussion of Professor Thompson's article, *loc. cit.*, p. 712.

[72] *Ibid.*, p. 700.

The most probable and most usual source of the hunting is no doubt a weak and especially a yielding magnetic field. Easy distortion of the field gives a wide latitude for speed fluctuations without the machine's losing synchronism, and the magnetic lines, pulled as it were, first in one direction and then in the other, act like elastic cords to increase the swaying movement, until, in some cases, the armature finally breaks away from them, that is to say, loses synchronism and refuses to run. The alternate distortion of the field easily explains the sparking at the brushes.

The remedy for this defect is to stiffen the field—both strengthen it, and by properly designing the pole-pieces prevent its distortion. The exciting coils should be placed on their extremity, as near as possible to the surface of the armature. Another remedy is to surround the pole-pieces at their extremities with a short-circuited ring or coil of copper, which may, if desirable, cover the pole-faces also. This acts as a damper to prevent distortion. It may occasion, however, considerable loss of power and a lowering of efficiency from 1 to 3 per cent.

Dissimilarity in the curves of electromotive force is a hypothetical rather than known cause of hunting. It does not appear to bear any necessary relation to the subject, however, as machines having wholly different and very irregular curves will often work together without any difficulty.[73] Steinmetz has suggested, however, that in three-phase machines the triple harmonic, which is the most important, will coincide in phase with and thus annihilate each other, whereas in a four-phase machine they will combine in a rotary effort which tends to revolve the machine backward at triple synchronism. It is not apparent how this could affect the speed of a synchronous machine.

The self-induction of the circuit is a point which may or may not have importance, but usually, no doubt, its effect is too insignificant to be considered, as in the case of alternating dynamos.[74]

---

[73] See, for instance, Steinmetz in *Trans. A. I. E. E.*, V. 12, p. 498.

[74] See Thompson, "Dynamo Electric Machinery," 4th Ed., p. 699.

A general remedy for hunting is to increase the angular momentum of the rotating part of the machine, and thereby make a variation of speed more difficult. This is the same remedy as increasing the flywheel capacity on an engine.

The subject need not here be treated with greater detail, but enough has been said to indicate it as a line requiring the attention of investigators and inventors.

Theory of the Two-coil Transformer.—The two-coil transformer does not need detailed treatment separately from the one-coil transformer, with regard to the points above considered, excepting in its current relations, output and efficiency; in other respects it is essentially identical with the latter. As will be evident, the total armature heating effect for the same output will be very much increased, and the output and efficiency much diminished, in relation to those of the single-coil machine, as there is no neutralization of armature currents.

Supposing, as before (page 56), the output of the $D\,C$ side to be $2\,C\,E$, the armature heating will be $2\,C^2\,r$, as above explained. The input of the $A\,C$ side of a monophase machine, at 100 per cent. efficiency, is then also $2\,C\,E$, and its maximum current $4\,C$—supposing the maximum pressure to be the same as on the $D\,C$ side—so that the heating effect in each half of the armature will be

$$\frac{(2\,C)^2}{2}\,\pi\,r,$$

and for the whole armature, $4\,\pi\,C^2 r$. Adding these together, we get for the total heating effect, $6\,\pi\,C^2\,r$, or three times that of the machine when run as a $D\,C$ generator at the same output, and

$$\frac{3\,\pi^2}{3\,\pi^2 - 16} = 2{\cdot}17$$

times that of a single-coil rotary of the same output. For the output at equal armature heating, we have, as on page 361,

$$O = \frac{C}{C_1} = \sqrt{\frac{1}{3}} = {\cdot}577$$

or little more than half that of the same machine run as a $D\,C$ generator. The efficiency will be correspondingly lowered.

For polyphase machines, taking the current values given on page 60,

3-phase, $W = \left(\frac{1{\cdot}54^2}{2} . 2\pi + 2\pi \right) C^2 r = 4{\cdot}37\,\pi\, C^2 r;$

4-phase, $W = \left(\frac{\sqrt{2}^2}{2} . 2\pi + 2\pi \right) C^2 r = 4\,\pi\, C^2 r;$

6-phase, $W = \left(\frac{1{\cdot}334^2}{2} . 2\pi + 2\pi \right) C^2 r = 3{\cdot}79\,\pi\, C^2 r.$

Proceeding, we obtain the following table for the two-coil rotary transformer:

Phases.	Heating for Given Output.			Output for Given Heating.	
		Ratio to		Ratio to	
	$\div C^2 r.$	*DC* gen'tor.	1-coil R. T.	*DC* gen'tor.	1-coil R. T.
Single	18·85	3	2·17	·577	·68
3	13·75	2·18	(3·7)	·677	(·52)
4	12·57	2	4·94	·707	·450
6	11·91	1·89	—	·729	—

The above values are calculated on the assumption that the pressure bears the same ratio on the two sides as in a one-coil transformer. This, however, from the well-known dynamo-formulæ, cannot affect the result.

It will be perceived that the superiority over the two-coil machine rapidly increases as we increase the number of phases. The output of the two-coil machine increases very slowly as we increase the number of phases, and can, of course, never equal that of the same machine as a *DC* dynamo; while the one-coil machine may have an output far above the latter.

For this reason also the efficiency of the two-coil machine, especially of the single-phase variety, is necessarily very low, and it is no wonder that those at the Tivoli-Rome installation were taken out (see page 365.) They have, however, the great merit of dispensing with stationary transformers, but in this respect they are inferior as a class to the type we shall next consider.

[*To be continued.*]

ELECTRICAL SECTION.

Stated Meeting, held December 20, 1900.

ELECTROCHEMICAL ACTION.

By C. J. Reed, Member of the Institute.

Chemical Energy.—In every chemical change, whether it be one of combination, dissociation, or substitution, there is a transformation of matter and a simultaneous transformation of energy. The changes in matter may all be determined by means of the balance, which enables us to measure the masses affected. The transformations of energy require for their determination, in addition to the balance, the aid of some instrument for measuring the energy that passes into or out of the system during the chemical change. Heat, being the only form of energy into which all other forms may be converted without loss, is the form best adapted for such determinations. The calorimeter is, therefore, as necessary for determining the energy communicated to or from a system undergoing chemical change as the balance is for determining the masses affected.

The energy communicated (evolved or absorbed) in very many thermochemical reactions has been determined in the form of heat with great care. The precision of such determinations is not comparable with that of our most refined physical measurements, but greatly exceeds that of any other method of determining the energy of chemical changes. In a great majority of cases a heat method is the only available one for making any determination at all. It is possible, in some specific cases, by the aid of hypotheses, calculations, and a combination of experimental researches on different lines of investigation, to determine the energy of a chemical change in the form of electrical energy without a calorimetric measurement. But the results of this method are not certain and are always based upon assump-

tions. The method is also applicable to only a comparatively few cases.

By means of the data established calorimetrically we are enabled to study with advantage and reasonable certainty all other energy changes that may be concerned in chemical reactions without resorting to any theory beyond the assumption that energy can be neither created nor destroyed.

The chemical energy of a system capable of undergoing chemical change is measured by its power of doing external work in some form, as a result of the chemical reaction alone, and does not include the power the system may possess of doing external work through a change in its temperature. The chemical energy of a system, as thus defined, may be either positive or negative. It is always static or potential in form and must be treated as potential energy.

When a chemical system evolves energy, due entirely to internal chemical change, it may be restored to its initial condition, only by absorbing from without, in some form, energy equivalent to the chemical potential energy lost.

In this respect there is no difference between chemical potential energy and ordinary energy of position. In other respects, however, they are very different. Ordinary energy of position is determined by mass and distance, and is independent of the specific natures and physical conditions of the bodies concerned; while chemical energy depends upon the masses, the specific natures of the bodies composing the system and the physical condition of the system, but, so far as we know, is independent of distances. We might distinguish these two forms of potential energy by considering the one as *molar*, because it affects masses, and the other as *molecular*, because it affects molecules only.

The Communication of Chemical Energy.—There are two methods or processes by which the energy of a chemical change may be communicated to or from a system comprising chemically reacting bodies. In one of these processes the communication of energy is by radiation and conduction; in the other by conduction only.

When the energy of a chemical reaction is communicable, wholly or in part, by radiation, it is in the form of either heat or light and is always measurable as heat. When the energy of a chemical reaction is communicable by conduction only, it is in the form of electrical energy.* The quantity of energy communicated by a system in a chemical reaction is, of course, entirely independent of the form or manner of its transformation or transmission and depends only upon the difference between the chemical energy of the initial and that of the final state of the system.

We may divide chemical reactions, with reference to the manner in which their energy is communicable, into two general classes, *thermochemical*, or those in which radiant energy is communicable; and *electrochemical*, or those in which electrical energy is communicable. A particular system of reagents may be capable of producing only thermochemical action, or it may be capable of producing electrochemical action under particular conditions, or it may be capable of producing both reactions simultaneously and independently. But the same particle of matter cannot be simultaneously subject to both reactions. The energy of a given pair of ultimate particles or atoms cannot be communicated partly as electrical and partly as radiant energy without a second transformation of some kind. An atom or molecule cannot undergo a given chemical change by two processes simultaneously. An atom of zinc, for example, may combine with chlorine either thermochemically, communicating heat, or electrochemically, communicating electrical energy, but cannot simultaneously undergo both changes. This is a corollary of Faraday's discovery that a definite quantity of any substance in undergoing electrochemical change corresponds to the passage of a definite quantity of electric current.

Evolution and Absorption of Energy.—In thermochemical reactions heat (and light) may be either evolved or absorbed.

* Chemical energy cannot be communicated by induction, and we are, therefore, not concerned here with the question of the nature of electric conduction, and for convenience we may consider electrical energy to be communicated by the wire or conductor carrying the current, rather than by the medium surrounding the conductor.

When heat is evolved at the expense of the chemical energy of a system, the reaction is said to be *exothermic*. When heat is absorbed with the accumulation of chemical energy within a system, the reaction is said to be *endothermic*. In electrochemical reactions electrical energy, instead of heat, is either evolved or absorbed as a result of the change. We have no specific terms, however, to indicate these particular kinds of reaction and it has been customary to speak of these changes also as exothermic and endothermic, although heat is in no way concerned. It is like speaking of the energy of a falling body as its *heat*.

In order to avoid this ambiguity and to state more exactly the relations of the various energy changes in electrochemical reactions, it will be convenient to specify the two kinds of electrochemical reactions by distinctive names. We shall, therefore, call those electrochemical changes, which evolve or generate electrical energy at the expense of chemical energy, *electrogenic* reactions, instead of exothermic, from ἠλεκτρον and γένεσις, signifying the generation of electrical energy; and those electrochemical reactions which absorb electrical and produce chemical energy, *electrothanic*, from ἤλεκτρον and θανεῖν, signifying the dying or vanishing of electrical energy. The processes corresponding to these transformations may be called respectively *electrogenesis* and *electrothanasis*.

A classification of chemical reactions, with reference to their energy changes, therefore, may be made as follows:

- CHEMICAL ACTION
  - Thermochemical (energy communicable by radiation)
    - Exothermic (evolving heat or light)
    - Endothermic (absorbing heat or light)
  - Electrochemical (energy communicable by conduction only)
    - Electrogenic (evolving electrical energy)
    - Electrothanic (absorbing electrical energy)

Thermochemical and electrochemical changes are strictly co-ordinate and both result in the same final products in

matter. They differ, as stated above, in the two distinct methods by which the energy corresponding to the chemical change is communicable and in the conditions necessary for the production of each of the two kinds of change. Zinc and chlorine, for example, may unite thermochemically and evolve heat, or electrochemically and evolve electrical energy, the resulting compound, zinc chloride, being the same in both cases. The reaction in the former case is exothermic and may result from the direct union of chlorine and zinc. In the latter, it is electrogenic and must result from a process of substitution.

Conditions of Thermochemical Action.—A thermochemical reaction requires only that a chemical system shall be brought to the proper conditions of temperature and pressure. The thermochemical reaction then takes place, generally throughout the system when the conditions and distribution are uniform, or locally at any point where the required conditions obtain.

Conditions of Electrochemical Action.—The conditions necessary for electrochemical action are very different from those required for thermochemical action. While a uniform mixture of the reacting bodies is always most favorable for thermochemical action, electrochemical action under such conditions is unknown. Electrochemical action takes place only at the bounding surface of a reacting body, and only at surfaces through which an electric current is either entering or leaving the reacting body. We have no evidence whatever of any species of electrochemical action affecting the chemical composition of the interior of a substance. A change of composition throughout the mass of a body may result, and in time generally does result in the case of liquid bodies, through the transportation of the products of electrochemical change, but the actual electrochemical changes occur only at the terminal surfaces.

Owing to this purely surface action in electrochemical change, it is necessary to classify and define electric conductors with reference to the manner in which an electric current may enter or leave them. Electrochemically there are two kinds of electric conductors, *electrodes* and *electrolytes*.

Electrodes.—If a direct, or continuous, electric current can be made to cross the junction of two different conductors without chemical action, the conductors are *electrodes.*

An electric current may, for example, be made to cross the junction of any two conducting chemical elements, such as the junction of two metals, or the junction of carbon and the metal, without any chemical change due to the current. Hence, all conducting chemical elements are electrodes. An electric current may also be made to cross the junction formed by a crystal of lead peroxide and a conducting element without chemical change. Hence, lead peroxide is also an electrode. Many metallic oxides and compounds *in the solid state* are electrodes.

Electrolytes.—If a direct, or continuous, electric current cannot be made to cross the junction of an electrode and a second conductor without chemical change, the second conductor is an *electrolyte.* All electrolytes are compounds and all conducting compounds in the liquid state, whether liquefied by fusion or solution, are electrolytes. There are many compounds which are non-conducting in the solid state, and which become electrolytes by fusion or solution. Some oxides, such as those of the alkaline earth metals, are non-conductors at low temperatures and become electrolytes at high temperatures without actually becoming liquid, although becoming somewhat softened.

Another condition necessary for electrochemical action is that at least one of the reacting substances shall be an electrolyte and that it shall undergo decomposition by a process of substitution or chemical displacement.

Electrochemical Systems.—An electrochemical system comprises two electrodes, each in contact with an electrolyte, the two electrolytes being electrically connected without the intervention of electrodes. Such a system is represented in *Figs. 1* and *2*, in which E and E' represent two electrodes, either of the same or of different material, and e, e' and e^2 represent electrolytes, all of which may be of the same or of different material. When the electrolytes are all of the same material they are usually regarded as a single electrolyte. There may intervene between the

two electrolytes, e and e', another single electrolyte, e^2, or any number of electrolytes in series, but no electrodes. While the electrolytes may all be of the same composition and apparently only a single uniform body, yet the system must be considered structurally as comprising two electrolytes in contact with each other and each in contact with its electrode, each electrode with its electrolyte constituting a distinct chemical system.

The electrochemical systems shown in *Figs. 1* and *2* are *inactive*, that is, incapable of electrochemical action in the condition shown. They may be rendered *active* by electrically joining the two electrodes, either directly or by the intervention of an additional or external conductor, provided the closed circuit so formed includes a source of electrical energy. Such a source of electrical energy may be contained in the

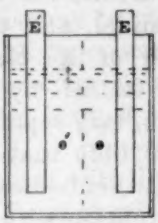


FIG. 1.

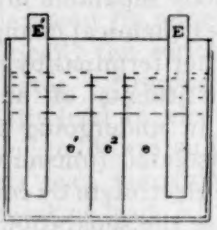


FIG. 2.

electrochemical system itself, or it may be included in the additional external conductor. If, in such a system, one electrode consists of zinc and the other of copper, each metal being in contact with a solution of one of its salts, the electrochemical system itself is a source of electrical energy. If the external conductor includes a dynamo, thermopile, or galvanic battery, the source of electrical energy is external to the electrochemical system. Evidently a closed circuit of this kind may include both internal and external sources of electrical energy.

The definition of an electrochemical system given above includes all known forms, whether they evolve or absorb energy and whatever may be the nature of the component parts of the system or of the external conductors used to render the system active, that is, to "close the circuit," and

whatever may be the source of the energy of the electric current.

The bounding surfaces of contact, at which the electrodes join the electrolytes, are always the loci of electrochemical action, and are the "poles" or terminals of the system.

Mixed Systems.—There may be several electrolytes mixed together in an electrochemical system, or several different electrodes in contact may be substituted for a single electrode. Under such conditions there are generally several different electrochemical reactions possible, all equally accessible to the same circuit. These different reagents are, by electrochemical action, successively exhausted in a particular order, as we shall see later.

An electrolyte, as already defined, is necessarily a compound body separable into two constituents, one of which undergoes chemical change at one terminal, and the other at the other terminal by separation out of the electrolyte. The constituents of an electrolyte (called by Faraday "ions"), in undergoing this separation, may separate in a free or isolated (uncombined) state, or they may separate from the electrolyte by combining with other bodies. In the latter case the separation and recombination with another body occur *in series* and simultaneously, the complete change constituting the electrochemical reaction. If, however, the constituents of an electrolyte are set free, that is, liberated, and subsequently enter into other combinations, such subsequent or secondary reactions are thermochemical and entirely independent of the electrochemical reaction. Such reactions are not in series with the electrochemical reaction. Secondary reactions may take place slowly or rapidly, depending on their nature and on the conditions present, but the speed of the electrochemical reaction is always dependent entirely upon the strength of the current, being unaffected by either temperature, concentrations or other conditions.

Kinds of Electrodes.—An electrode, as defined above, may be either a chemical element or a conducting compound. The zinc and copper electrodes of the Daniell's battery are

elementary, but the mass of lead peroxide, comprising one electrode of a lead accumulator, and the copper oxide, comprising one electrode of the Lalande battery, are examples of compound electrodes. An electrode is not to be confounded with the mechanical support which is sometimes used to retain it in position. An electrode of lead peroxide, for example, is generally, though not necessarily, supported in position by an adherent mass of metallic lead, which acts also as a conductor. The action of the lead peroxide electrode is exactly the same, however, whether the lead support is present or not. In reality only the active electrochemical surface belongs to the electrochemical system, the entire mass of the electrode, except that at the surface of electrochemical action, being only a conductor, through which the electrochemical system communicates with external bodies.

This may be more fully understood by reference to *Fig. 3*, which represents diagrammatically the series of conductors constituting a lead accumulator. *A* represents a mass of solid lead, *B*, a mass of spongy lead in electric contact with *A*. *C* represents an electrolyte (dilute sulphuric acid) in contact with *B*. *D* represents lead peroxide in contact with *C* and also with a second mass of lead, *E*. An electric current can pass through the electrolyte only by entering or leaving the conductors, *B* and *D*, the spongy lead at one terminal and the lead peroxide at the other. The current passes between the spongy lead and the conducting mass of inactive lead without electrochemical action. It also passes between the lead peroxide and the metallic lead without electrochemical action. Therefore, *B* and *D* are electrodes, according to definition, while *A* and *E* are mere conductors, which may also act as mechanical supports.

An electrode may, or may not, be a reacting component in an electrochemical system, but an electrolyte is always a reacting component and always undergoes electrochemical decomposition. In the lead accumulator the electrolyte and both electrodes are reacting components of the system, while in the Bunsen cell the zinc electrode and both electrolytes (H_2SO_4Aq and HNO_3) are the reacting components,

the carbon electrode undergoing no chemical reaction. The carbon electrode in this case may be replaced by any conducting element not affected by nitric acid, such as gold, platinum, or *aluminium* without materially affecting the electromotive force. With currents of very high tension the electrodes may even consist of air or other gases. Faraday decomposed solutions of sodium sulphate, using air electrodes and a static machine as the source of electrical energy, and had no difficulty in separating the acid and alkali at the terminals of the electrolyte.

Poles.—A *pole or terminal* of an electrolyte or electrode is the bounding surface which an electric current crosses in entering or leaving. The negative terminal of a conductor is the surface through which a current leaves, and the

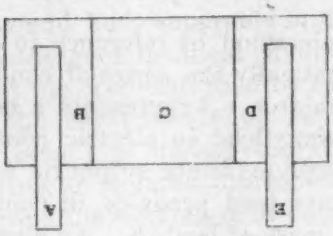


FIG. 3.

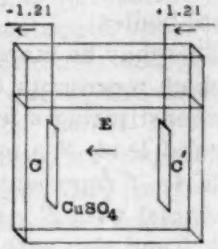


FIG. 4.

positive terminal is the surface through which a current enters.

Nature of Electrochemical Action.—Electrochemical action evidently cannot take place uniformly throughout the mass of the reacting system, as does thermochemical action, but only at separated and generally distant surfaces, which are always the terminals of an electrolyte. These surfaces must also be the terminals of electrodes or of other electrolytes. They may for convenience be called *electrolytic junctions.*

Whether these junctions, or loci of electrochemical action, are near together or remote from each other is quite immaterial, so far as the nature of the reaction is concerned. No chemical change whatever is produced in the body of the electrolyte, the changes in composition being produced

by the diffusion or mechanical convection of the products of electrochemical action, which are formed at the terminals of the electrolyte.

Changes in density are also produced in an electrolyte during electrochemical action. Changes in density are most marked near the terminals of an electrolyte, but extend throughout the electrolyte after prolonged action.

According to one theory these changes in the distribution and concentration of an electrolyte during electrochemical change are ascribed to the directive action of the electric current and the motion of electrified particles with different velocities. Such a supposition is entirely unnecessary, however, as the same result would follow from the changes in composition, if no current were present. That is, if the same chemical changes were produced at the terminals without the presence or agency of an electric current, the observed changes in density would still take place.

As there are always two separate terminals or electrolytic junctions in an electrochemical system, through which the electric current must enter and leave the electrolytic chain, in order to communicate electrical energy, there must necessarily, during electrochemical action, always be two separate and simultaneous chemical reactions, one at each terminal. These two reactions, occurring in series at the two terminals, are always of an opposite or different character, and are so related to each other that the reaction at one terminal is impossible without the reaction at the other.

An electrochemical system, or cell, as it is usually called, of the simplest type is shown in *Fig. 4*, in which the electrodes C and C' are plates of copper and the electrolyte E is a solution of uniform and definite density and temperature, containing a salt of the same metal, for example, copper sulphate. In this case both electrolytes are of the same material and both electrodes are of the same material. Such a cell is not capable of electrogenic action. That is, this electrochemical system is incapable of communicating any of its chemical potential energy in the form of electrical

energy.* Let us suppose, therefore, that the electrodes of this cell are connected by a conductor to form a closed circuit, which includes some external source of electrical energy capable of sending an electric current through the cell in the direction indicated by the arrow.

The electric current, in passing from the copper electrode C' into the solution, causes the copper to dissolve from this electrode by electrochemical action, forming copper sulphate. It has been determined by calorimetric measurements that a gram of copper, in passing into combination to form copper sulphate, always loses a definite quantity of chemical potential energy, numerically equivalent to 885 gram-calories of heat. The particles of copper evidently contain this energy while they remain a part of the copper plate. But after crossing the electrolytic junction and becoming copper sulphate, they no longer possess this potential energy. The inevitable conclusion is that this chemical energy must have been lost as such by the copper in the act of crossing the electrolytic junction between the copper electrode C' and the electrolyte, since, before crossing this surface, the copper has the energy of chemical separation, and, after crossing the junction, it has not the energy of separation. It is found that no heat is developed or absorbed at this junction, except that which

---

* This does not imply that the system is incapable of giving up electrical energy at the expense of its heat, or of any other form of energy, except chemical, which it may possess. For example, if the circuit be closed by connecting the electrodes C and C' through any external, inert system of conductors, to which it is desired to impart electrical energy, we may abstract electrical energy from the electrochemical system by cooling one of its electrolytic junctions. An electric current would then flow through the circuit, passing from the copper to the electrolyte at the cold junction. The electrochemical system, in this case, would not only communicate electrical energy to the external conducting system, but it would also simultaneously communicate heat to some external body at a lower temperature. The current flowing through the cell would also cause electrochemical action at both electrolytic junctions. But, although the electrochemical system has given up electrical energy and has, in communicating that energy, undergone electrochemical action at both junctions, it will be found that the chemical state and condition of the system is unchanged, and that the system has lost no energy except heat, due to the reduction of its temperature.

is accounted for as necessarily due to thermoelectric action. Hence, the chemical energy which disappears at this junction could neither have been communicated to another system nor transmitted to another part of the same system in any known form, except that of electrical energy. We must conclude, therefore, that this chemical energy is added as electrical energy to that of the electric current simultaneously crossing the junction. This could occur only by the development of a definite electromotive force at the junction tending to maintain the current. This electromotive force must be directly proportional to the chemical energy lost per unit of time. In other words, the electromotive force, multiplied by the current, must equal the chemical energy simultaneously lost. The electromotive force in this particular case is 1·21 volts, and is accounted for elsewhere in the circuit.

The electrochemical reaction at this terminal of the cell, therefore, is entirely electrogenic. It adds an electromotive force of 1·21 volts to that of the circuit, but neither evolves nor absorbs heat, though there may be and generally is incidentally at this point a simultaneous change of *electrical energy into heat or of heat into electrical energy by thermoelectric action.*

This chemical electromotive force of 1·21 volts cannot be directly measured, because electrochemical action cannot occur at a single terminal only of an electrolyte, and an electric circuit containing only one terminal of an electrolyte is as impossible as a dynamo with only one brush. But when the chemical energy of the reaction is known in the form of heat or in any other form, this electromotive force is determined by calculation on the assumption that energy can be neither created nor destroyed; because this electromotive force, multiplied by the strength of the current at any time flowing, is equal to the power, which expresses the rate at which chemical energy is disappearing by the electrochemical dissolving of the copper. It is to be understood that we are referring to the electrochemical electromotive force only, and not to thermoelectric or other incidental simultaneous transformations.

In passing out of the electrolyte to the electrode, *C*, the current causes an equal quantity of copper to pass out of the solution by electrochemical action and be deposited on that electrode in the metallic state. The copper, in crossing the junction between the electrolyte and the plate, *C*, that is, in passing from the state of combination as copper sulphate into the free state as metallic copper, acquires energy of chemical separation, which could be supplied only by the energy of the electric current. Before crossing this junction the copper has not this energy of separation, but after crossing the junction it has the energy of chemical separation. We determine by the same method, therefore, that at this junction an electromotive force of 1·21 volts is absorbed from the electromotive force of the circuit, the action being entirely electrothanic.

The electromotive force absorbed by electrothanic action at *C* in this particular cell is, therefore, exactly equal to the electromotive force produced by electrogenic action at *C'*. As these two electromotive forces are equal and opposed to each other, a galvanometer connected to the electrodes will show no difference of potential due to electrochemical action, but will show every difference of potential that may exist due to other causes. Such differences of potential are always present, however, when a current is flowing, that is, when the cell is in action. The electromotive force of this particular cell, as found by a voltmeter connected to its terminals, is, therefore, always a measure, not of the electrochemical electromotive force, but of the sum of all electromotive forces *due to electric inversions other than the electrochemical*, which are taking place in the cell. When no current is passing, there can be no such electric inversions and no electromotive force.

If it were possible to connect one terminal of a galvanometer to the electrolyte at any point between *C* and *C'*, without introducing an electrode, so that a current due to the electromotive force of one terminal only, of the electrolyte, could flow through the galvanometer, we could then measure directly the electromotive force of a single terminal of the electrolyte. But no method of doing this has

yet been found. The best we have yet been able to do is to measure the algebraic sum of all electromotive forces between two terminals of an electrolyte. The introduction of a third, or so-called "normal" electrode, does not help us in the least, as the electromotive force at the "normal" electrode is always added to that we are measuring. This is evident from the fact that an electric current cannot cross the junction of an electrode and an electrolyte without electrochemical action, and the fact that there is no known chemical action that does not either evolve or absorb energy.

It is evident that the reaction which takes place at the terminal, C', could not occur alone, because we could not add copper to copper sulphate and produce copper sulphate. In other words, $Cu + CuSO_4 = CuSO_4$ is not an equation, either mathematically or chemically, and cannot represent a chemical reaction. Similarly, the reaction at the terminal, C, represented by $CuSO_4 = Cu + CuSO_4$, would, of itself, be impossible. We cannot remove copper from copper sulphate and leave copper sulphate. But by adding these two inequalities together in the proper order in which they occur, we obtain $Cu + 2CuSO_4 = 2CuSO_4 + Cu$, which is an equation representing the sum of the electrochemical reactions at both terminals, that is, the electrochemical action of the system. This equation tells us also that the quantities of copper and copper sulphate and the chemical energy of the system are the same in the initial and final states, though some particles of matter have changed position within the system, and the mechanical energy may not be the same in the two states. Some particles of copper have been transferred from C' and an equal number transferred to C, and the $CuSO_4$ is stronger at C' than at C. Some heat has also been generated within the cell, but the energy necessary for these changes has been received from an external source, namely, the external source of electrical energy included in the circuit.

In all electrochemical reactions both the mechanism and the *modus operandi* are the same as in the electrolytic cell just described. Electrochemical cells may differ in details of

construction, in the nature of the materials used, and in the quantities of electrogenic and electrothanic action, but they never depart from this method of operation (substitution), and no electrochemical reaction is known between two chemical elements without the agency of an intervening electrolyte. Even the most highly electro-positive elements, such as lithium, potassium, sodium or zinc, when brought in contact with the most powerful oxidizing elements, such as free bromine or chlorine, produce heat, but no electrical energy.

If, in the agenic cell shown in *Fig. 4*, we insert a vertical wall or partition of porous clay, so as to divide the cell into two compartments, each containing an electrode and a portion of the adjacent electrolyte, we do not interrupt the con-

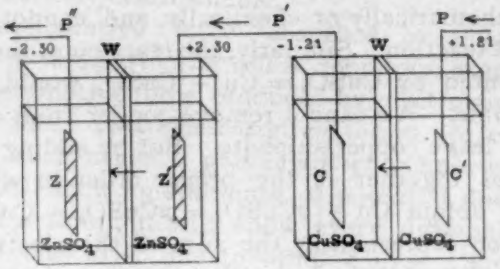


FIG. 5.

tinuity of the electrolyte and do not, therefore, interfere with the electrochemical action of the cell, except by slightly increasing its resistance. We do, however, by such a partition prevent any rapid mechanical intermixture of the two portions of the electrolyte, which are in contact with the two electrodes.

Fig. 5 shows two such agenic cells connected in series, one having copper electrodes, *C* and *C'*, and an electrolyte containing copper sulphate; the other having zinc electrodes, *Z* and *Z'*, and an electrolyte containing zinc sulphate, each cell being divided into two compartments by a porous partition, *W*. As both of these cells are agenic, there is no difference of potential between any of the points *P*, *P'* and *P''*, either on open or closed circuit, if the

circuit includes no other source of electrical energy, the two equal and opposite electromotive forces in each cell producing a condition of perfect equilibrium. If the circuit is rendered active by including an external source of electrical energy, there will be, when the circuit is closed, a difference of potential between any two of the points, P, P' and P'', due to the Joule effect and to thermoelectric inversions, but none due to electrochemical change, as the algebraic sum of the electrogenic and electrothanic actions between any pair of these terminals is zero.

Let us now suppose an electric current to be sent through this series in the direction indicated by the arrow. As already explained, the dissolving of metallic copper from the electrode, C', adds an electromotive force of 1·21

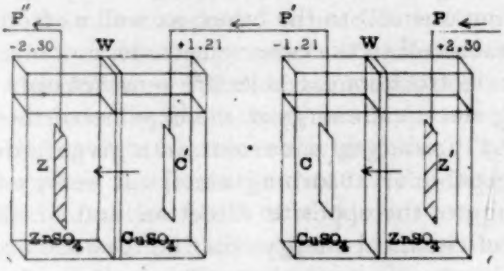


FIG. 6.

volts to that of the circuit, and the deposition of metallic copper at C absorbs an electromotive force of 1·21 volts from that of the circuit. For the same reasons the dissolving of metallic zinc from the electrode, Z', adds to the circuit at that point an electromotive force of 2·30 volts, and the deposition of metallic zinc at the electrode, Z, absorbs 2·30 volts from the circuit. The algebraic sum of these electromotive forces is zero, regardless of the direction of the current.

But it is possible, without altering any of these electrochemical reactions in any way, to interchange the contents of any two compartments or semi-cells. We may, for example, interchange the C' and Z' compartments, giving us the arrangement shown in *Fig. 6*. The algebraic sum

of the four electromotive forces of the two electrochemical systems is still zero, that is, there is no chemical electromotive force between P and P''. But between the points P and P' the sum of the electromotive forces is 2·30 — 1·21 = 1·06 volts, tending to produce a current in the direction indicated by the arrow; and between the points P' and P'' the sum is also 2·30 — 1·21 = 1·09 volts, tending to produce a current opposed to the arrow. In other words, the two agenic cells have, by the interchange of compartments, been converted into two cells having opposed and equal electromotive forces. With a current now flowing in either direction, one cell is electrothanic and the other is electrogenic. The sum of their electromotive forces is still zero, and the slightest external electromotive force will send a current through the circuit, causing a transfer of chemical energy from one cell to the other, as well as from one electrode of each cell to the other electrode.

These electrochemical cells are now not only capable of supplying electrical energy at the expense of their chemical energy, by producing a current in a given direction, but are also capable of absorbing electrical energy from a current flowing in the opposite direction and of storing it in the form of chemical energy; that is, they are accumulators as well as galvanic batteries. This cell is also the well-known Daniell cell.

Reversibility of Electrochemical Action.—As an electric current cannot pass into or out of an electrolyte (or chain of electrolytes) without either electrogenic or electrothanic action, every electrochemical cell having dissimilar electrodes is, theoretically, an accumulator when the current passes in one direction and a galvanic battery when it passes in the opposite direction. But in most electrochemical cells the chemical energy accumulated by electrothanic action is not available again for electrogenic action, because the products of electrothanasis pass out of the sphere of action, either by undergoing other chemical changes or by being transported out of the circuit. For the same reasons the chemical energy expended in a primary battery by electrogenic action cannot generally be restored by electrothanic action.

We ought, therefore, to make a distinction between accumulators and storage batteries, as all accumulators are not necessarily storage batteries. That is, electrochemical cells are not all reversible in practice, though they are in theory.

A chemical element or compound, which, in undergoing electrochemical action, is electrogenic and loses chemical energy, may be conveniently called an *electrogen*, and one which is electrothanic, absorbing electrical energy, an *electrothan*.

We have already seen that the same substance may be an electrogen in one cell and an electrothan in another, and that this may be true in the same cell through a reversal of the current.

When zinc, copper or any other metal is separated electrochemically from a compound whose formation heat is positive, the action is always electrothanic and the substance is an electrothan. When these substances combine again electrochemically, the action is always electrogenic and the combining substances are electrogens. The reverse is always true when the formation heat of the compound is negative. The formation heats of all known compounds of the following elements and some others are positive:

Potassium,	Arsenic,
Sodium,	Mercury,
Lithium,	Manganese,
Aluminium,	Zinc,
Barium,	Cadmium,
Strontium,	Iron,
Calcium,	Thallium,
Magnesium,	Copper,
Tin,	Silver,
Lead,	Cobalt,
Sulphur,	Nickel,
Selenium,	Antimony,
Tellurium,	Bismuth,

Chromium.

Hence, these substances, in passing from the free or metallic state into combination of any kind by electrochemical action, are always electrogens and increase the electromo-

tive force of the current flowing from them into the electrolyte. In passing from combination into the free or metallic state by electrochemical action these substances always act as electrothans, opposing a counter-electromotive force to that of the current, which deposits them from an electrolyte.

There are a few compounds of a few elements whose formation heats are negative. They are chiefly compounds of the following elements with one another:

Gold,	Hydrogen,
Bromine,	Nitrogen,
Iodine,	Carbon,
Chlorine,	Oxygen.

These elements, therefore, in passing from the free state into certain particular combinations, act as electrothans, and, in passing from these combinations into the free state, act as electrogens. This is not true, however, of all compounds of these elements.

Electrogenic Power.—The electrogenic power of a compound may be defined as the intensity of the electrical energy evolved by the electrochemical formation of the compound. It is proportional to and measured by the formation heat of the same compound, formed thermochemically. Electrothanic power is merely negative electrogenic power. Or, it may be defined as the intensity of the electrical energy absorbed by the electrochemical formation of the compound.

In the following table of electrogenic powers the chemical symbols, the formation heats expressed in calories, and the corresponding electrochemical electromotive forces or electrogenic powers, expressed in volts, of some of the salts of the more common metals are given. The table might have been greatly extended by adding the iodides and other salts of the metals, but these were thought to be sufficient for the purpose of illustration.

TABLE OF ELECTROGENIC POWERS.

Chlorides.	Calories.	Volts.	Bromides.	Calories.	Volts.	Oxides.	Calories.	Volts.	Sulphates.	Calories.	Volts.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
$LiCl$	102300	4·40	$LiBr$	91500	3·94	Li_2O	83600	3·59	Li_2SO_4	99250	4·27
KCl	101200	4·35	KBr	90400	3·89	K_2O	82600	3·55	K_2SO_4	98800	4·25
$SrCl_2$	97925	4·21	$SrBr_2$	87100	3·75	SrO	79200	3·40	$SrSO_4$	94550	4·07
$NaCl$	96600	4·15	$NaBr$	85800	3·69	Na_2O	77950	3·35	Na_2SO_4	93700	4·03
$CaCl_2$	93700	4·03	$CaBr_2$	82900	3·57	CaO	74800	3·22	$CaSO_4$	90350	3·88
$MgCl_2$	93550	4·02	$MgBr_2$	82300	3·55	MgO	74400	3·20	$MgSO_4$	90000	3·87
Al_2Cl_6	79370	3·41	Al_2Br_6	69100	2·98	Al_2O_3	65500	2·82	$Al_2(SO_4)_3$	76070	3·27
$MnCl_2$	64300	2·77	$MnBr_2$	53500	2·30	MnO	47550	2·02	$MnSO_4$	61050	2·63
$ZnCl_2$	56500	2·43	$ZnBr_2$	45700	1·97	ZnO	41750	1·80	$ZnSO_4$	53450	2·30
$FeCl_2$	50050	2·15	$FeBr_2$	39250	1·69	FeO	34450	1·48	$FeSO_4$	46900	2·02
$CdCl_2$	48200	2·07	$CdBr_2$	38050	1·64	CdO	33150	1·43	$CdSO_4$	45250	1·95
$CoCl_2$	47500	2·04	$CoBr_2$	36700	1·58	CoO	32050	1·38	$CoSO_4$	43900	1·89
$NiCl_2$	46950	2·02	$NiBr_2$	36150	1·56	NiO	30750	1·32	$NiSO_4$	43800	1·89
Fe_2Cl_6	42620	1·83	Fe_2Br_6	31818	1·37	Fe_2O_3	32200	1·39	$Fe_2(SO_4)_3$	37870	1·63
$SnCl_2$	40650	1·75	$SnBr_2$	29950	1·29	SnO	35350	1·52	—	—	—
HCl	39400	1·69	HBr	28600	1·23	H_2O	34500	1·48	H_2SO_4	34500	1·48
$SnCl_4$	39575	1·70	$SnBr_4$	28650	1·23	SnO_2	35350	1·52	—	—	—
$TlCl$	38400	1·65	$TlBr$	41400	1·78	Tl_2O	19850	0·85	Tl_2SO_4	34500	1·48
$PbCl_2$	38950	1·68	$PbBr_2$	28150	1·21	PbO	25400	1·09	$PbSO_4$	37300	1·61
$AgCl$	29000	1·25	$AgBr$	23400	1·01	Ag_2O	3500	0·15	Ag_2SO_4	10750	0·47
$CuCl_2$	31250	1·34	$CuBr_2$	20450	0·86	CuO	18850	0·81	$CuSO_4$	28200	1·21
$HgCl_2$	25150	1·08	$HgBr_2$	18600	0·80	HgO	10750	0·46	$HgSO_4$	1200	0·52
$AuCl_3$	9100	0·39	$AuBr_3$	1870	0·08	Au_2O_3	— 1900	— ·08	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	Cl_2O_5	— 2535	— ·11	—	—	—
—	—	—	—	—	—	Cl_2O	— 2850	— ·12	—	—	—

Columns I, IV, VII and X give the chemical symbols of the chlorides, bromides, oxides and sulphates respectively. Columns II, V, VIII and XI give in gram-calories the formation heat or chemical energy of one univalent electrochemical equivalent, and columns III, VI, IX and XII, the electrogenic powers corresponding to this energy.

The numbers in the energy columns represent the chemical energy of the quantity of each substance, which is

electrochemically equivalent to 1 gram of hydrogen, that is, the energy evolved or absorbed in an electrochemical reaction during the passage of an electric current, which simultaneously liberates 1 gram of hydrogen in a voltameter. These numbers express also in a certain unit the electromotive force added to or absorbed from the circuit at the terminal of the cell, in which the substance takes part in the electrochemical action. Multiplying the numbers in columns II, V, VIII and XI by the constant, ·000043, we obtain, in columns III, VI, IX and XII, these electromotive forces in volts. This electrogenic power, or electrical intensity, represents also the degree of electro-positive character of the metals in the particular compounds given. The constant, ·000043, is obtained by dividing 4·151, the number of watt-seconds equivalent to a gram-calorie, by 96,540 (Ostwald), the number of coulombs required to liberate one univalent gram-electrochemical equivalent of any substance.

To obtain the exact electrogenic power of a compound formed from gases that undergo condensation, we must subtract from the formation heat the energy required to expand the gases again to atmospheric pressure. For example, to expand the oxygen and hydrogen, that forms a gram-molecule of H_2O, would require about 408 gram-calories, equivalent to an electrogenic power of 0·0175 volt. The exact electrogenic power of H_2O is, therefore, 1·484 — 0·0175 = 1·466 volts.

The chemical energy of a compound, and, consequently, its electrogenic power, is not a quantity inherent in one of the components, but it depends also upon the other substance with which it combines. That is, the energy of a chemical reaction is not primarily inherent in any one of the reacting members, but belongs to the system as a whole, as a result of the primal separation of the several reagents and of the work or energy expended in producing such separation.

Although it is evident from this table that the energy of a combination does not depend on either constituent alone, nevertheless, the simple numerical relations between chlor-

ides and bromides indicate that this energy may be the sum of two or more constants inherent in the several elements.

Galvanic Batteries.—From a table of electrogenic powers, such as the above, we may easily construct a great variety of Daniell cells, or galvanic batteries, of predetermined electrochemical electromotive force by substituting any metal in the list and its chloride, bromide, oxide or sulphate for the copper and copper sulphate in one of the cells shown in *Fig. 6*, or by substituting any metal in the list and one of its salts for the zinc and zinc sulphate, or by replacing both copper and zinc by two of the metals in the list, each in contact with one of its salts. For example, metallic lithium and lithium chloride in one compartment of the cell, with gold and auric chloride in the other, would give an electromotive force of $4{\cdot}40 - 0{\cdot}08 = 4{\cdot}32$ volts. In such a cell we may always use, as a substitute for an electrothanic metal (cathode), without altering the electromotive force, any conductor not electrochemically affected by the electrolyte; because such a conductor is soon plated electrolytically with a deposit of the electrothanic metal. For example, in the cell consisting of lithium and gold with their chlorides we may use a carbon cathode instead of the gold cathode, because on the passage of any current (in the electrogenic direction) gold is deposited on the carbon and it acts exactly as a plate of solid gold. In the copper-zinc cell we may for the same reason use carbon instead of copper without altering the electromotive force. In fact, the electromotive force does not depend in the least on the nature of the metal that passes out of solution, but entirely upon the chemical energy of the reaction, through which it is deposited. Nor does it depend on the nature of the electrodes, but solely on the energy of the reactions occurring at their surfaces.

Limits of Electrogenic Power.—About 4·5 volts is the upper limit of electrochemical electromotive force theoretically obtainable in any single electrochemical system by any combination of known substances, except possibly compounds of caesium, whose chemical energies have not been determined. In addition to the electromotive force thus prede-

termined, there are always thermoelectric transformations and Joule effects taking place in various parts of the system, whenever a current passes. But these are incidental and only affect the final result by being superimposed upon the electrochemical changes.

It may, nevertheless, and sometimes does, happen that these incidental transformations overbalance and entirely mask the electrochemical changes. For example, in the celebrated "carbon consuming cell" of Dr. Jacques (originally invented by Archereau), the electrothanic exceeds the electrogenic action by about 0·33 volt. As an electrochemical system, therefore, the Jacques cell is electrothanic. The thermo-electromotive force of this cell is opposed to and exceeds the sum of the electrochemical electromotive forces by about 1 volt, making it resemble a galvanic cell. In action it gives a thermoelectric current, which by an electrothanic reaction causes chemical energy to accumulate, oxidizing carbon and reducing iron.

This peculiar coincidence, that the thermoelectric action happens to be in the direction to cause oxidation of the carbon, led not only Dr. Jacques, but other eminent physicists, to believe that the energy of the cell was of galvanic, that is, electrogenic origin. An examination of the thermochemical data of this cell, however, which has been given elsewhere,* shows that such a conclusion is untenable.

The question arises, if electrochemical action is always of the same nature as that described above, what is the difference between electrolytic and galvanic action, since both are electrochemical? There is no difference whatever, except in the relative quantities of electrogenic and electrothanic action. In certain cells the electrogenic action exceeds the electrothanic, and in some particular cases there is no electrothanic action, the action being electrogenic at both terminals of the electrolyte. Such cells, in which the electrogenic action predominates, necessarily evolve electrical energy and we call them galvanic batteries. In other cells both reactions may be electrothanic, or the electro-

* *Electrical World*, January 2, 1897.

thanic may exceed the electrogenic action. These cells necessarily absorb electrical energy and acquire chemical energy when in action. They may be distinguished by calling them electrothanic cells. When the electrothanic equals the electrogenic action and the chemical energy is the same in the initial and final states, the cell may be called *agenic*, because it does not generate either chemical or electrical energy. But whether an electrochemical cell is electrogenic, electrothanic or agenic, it is always electrolytic, that is, it operates always by the electrolysis or decomposition of an electrolyte.

Calculation of Electromotive Force.—Whenever an electric current passes through an electrochemical cell there is always a conversion of electrical energy into heat, due to the electrical resistance of the materials composing the cell (Joule effect). This necessitates either a change of temperature or the communication of heat. If the cell is agenic, this could take place only by thermoelectric inversion, which would add to the electrogenic power a thermo-electromotive force proportional to the absolute temperature and the temperature coëfficient.

The calculation of the electromotive force of an electrochemical system in action can, therefore, be made only when its thermochemical constants, its resistance, and its thermoelectric, or temperature coëfficient are known. It is evident, however, that the term for temperature is not to be applied in calculating the electrogenic power of a system at the temperature at which its thermochemical constants have been determined.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held January 26, 1901.

OIL OF WALNUTS (JUGLANS NIGRA, L.).

BY LYMAN F. KEBLER, Member of the Institute.

Frequent and repeated efforts were made to secure a pure oil of walnuts, with the invariable result that the dealers were either unable to supply it, or oils like the following were sent:

No. 1. *Walnut Oil, White.*—This article was colorless, of a sweetish taste, with a peppermint-like flavor and soluble in water and 92 per cent. and 50 per cent. alcohol. Farther investigation showed it to be diluted glycerin, flavored with a menthol-like body.

No. 2. *Walnut Oil, Conc.*—The word concentrated immediately cast a halo of suspicion about this oil, and on submitting it to a fractional distillation about 80 per cent. came over between 78° and 85° C., which was chiefly ethyl alcohol. Then the thermometer rose rapidly to 205° C., which is the boiling point of nitrobenzene (oil of mirbane) and the odor confirmed the boiling point. A small amount of non-volatile matter was left.

When it is remembered that oil of walnuts is chiefly used by artists for paints, because it dries into a varnish which is less liable to crack than linseed oil varnish, the enormity of such adulterations becomes self-evident.

Having been unable to secure an oil of good quality, walnut kernels were secured, ground, and the oil expressed by means of a hydraulic press. In this way 25 per cent. of oil was obtained, while the kernels actually contained 66 per cent. of oil. It was thus deemed of interest to investigate the oil, inasmuch as no such examination seems to have been made.

The oil generally used is that obtained from *Juglans regia*, L., a tree indigenous to Persia and cultivated in Europe and America. The kernels of this nut contain from

30 per cent. to 40 per cent. of "virgin" oil. The fresh cold drawn oil,* is limpid, nearly colorless or pale greenish-yellow and of agreeable taste and odor. Has a specific gravity of 0·925 to 0·9265 at 15° C., saponification number 186–197, iodine value 142 to 151·7, fusing point of fatty acids 16° to 20° C., dries well and is said to be brought into this country from France and Switzerland in 110-gallon tuns.

Hickory nut oil resembles the above walnut oil very much and is known as "American Nut Oil."

Wm. T. Brannt (1896, "A Practical Treatise on Vegetable Fats and Oils," Vol. II, 37) says "oil of black walnuts is sometimes expressed, but is of little value." On examining the cold pressed black walnut oil, the following physical and chemical constants were obtained: It is limpid, of a straw yellow color, possesses a pleasant, agreeable walnut-like odor and taste, becomes turbid at 12° C., has a specific gravity of 0·9215 at 15° C., saponification number 190·1–191·5, acid number 8·6–9, ether number 181·5–182·5, Hehner's number 92·77, Reichart-Missel value 15 cubic centimeters, iodine value 141·4–142·7, melting point of fatty acids 0° C.

The drying qualities are excellent, equal, if not superior in this respect, to linseed oil, leaving a tenacious, flexible, transparent film. An artist on using it pronounced it a very satisfactory article for fine painting.

BOOK NOTICES.

Engine Tests, embracing the results of over one hundred feed-water tests and other investigations on various kinds of steam engines, conducted by the author. By Geo. H. Barnes, S.B., M. Soc. Mech. Eng's, etc. (8vo, pp. 339.) New York: D. Van Nostrand Co. 1900. (Price, $4.00.)

As an advisory contribution for the use of engineers engaged in planning and estimating on industrial steam plants, the data presented in this work, based as they are on the results obtained from actual tests, should relieve them from much embarrassment in reaching reliable conclusions. W.

* "Chemical Analysis of Oils, Fats, Waxes, etc.," by J. Lewkowitsch, 1898, p. 350.

Dynamo-Electric Machinery; its construction, design and operation. Direct Current Machines. By Samuel Sheldon, A.M., Ph.D., assisted by Hobart Mason, B.S. (8vo, pp. 281.) Published by D. Van Nostrand Co., New York. 1900. (Price, $2.50.)

This work has been prepared as a text-book for the courses in electrical engineering given in the technical schools, following especially the lines of the lectures given in the Polytechnic Institute of Brooklyn. It will be found equally useful to the general reader. W.

Chemisch-Calorische Untersuchungen über Generatoren und Martiniöfen. Von Hans v. Jüptner und Friederich Toldt. 2te Auflage. Leipzig: Arthur Felix. 1900. 8vo, pp. 96. (Price, R.M. 3.20.)

This work gives the results of an experimental study of the heat effects capable of realization in the improved furnaces of Siemens and Martin. They will be found to be of special value by metallurgical engineers whose professional work embraces the use of furnaces of this type. W.

Modern Electric Railway Motors. By George T. Hanchett, S.B., M. Inst. Elec. Engs. (8vo, pp. 200–iv.) New York: Street Railway Publishing Company. 1900.

The purpose of this work is to describe and explain the operation of the present railway electric motor. The state of the art considered in the work is so unstable that the author finds it necessary to apologize to his readers for the fact that "even during the process of preparing this short work for the press, it has been necessary to make substantial changes in the text to bring it down to date." The data presented in the work have been revised by the engineering forces of the several manufacturers whose products are described, and the work is a satisfactory exposition of the present practice of constructing and operating the railway electric motor. W.

Die Berechnung der Zentrifugalregulatoren. Von J. Bartl, Professor an der k. k. Hochschule zu Graz. Mit 27 in den Text gedruckten Figuren. Leipzig: Arthur Felix. 1900. Pp. 88, 8vo. (Price, R.M. 3.50.)

The above entitled work is a strictly mathematical treatment of the subject of centrifugal governors, embracing every known form of this type of apparatus. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, April 17, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 17, 1901.

President JOHN BIRKINBINE in the chair.

Present, 162 members and visitors.

Additions to membership since last month, 15.

The President made the statement that the business affairs of the Institute growing out of its association with the Philadelphia Museums in conducting

the late National Export Exposition had been finally closed by the payment to the Institute of the sum of $10,000, which represented the profit accruing to the Institute for its coöperation in the work.

The paper of the evening was presented by Mr. Chas. Day, who gave an account of the Taylor-White Tool Steel Process. Mr. Day based his remarks upon the experience made with these tools in the works of the Link-Belt Engineering Co., of Philadelphia. The paper was fully illustrated by specimen tools, chips of steel and cast iron, with records attached of speed of tool, depth of cut, etc., etc. Some discussion followed. This paper, with discussion thereon, is referred for publication, and the subject of the invention was, on motion, referred to the Committee on Science and the Arts.

The Secretary gave an informal talk on the Bermuda Islands, detailing some observations he had made during a recent visit to the Islands. The subject was illustrated with a series of lantern slides.

The Secretary also called attention to the fact that the Horological Society of Philadelphia had deposited in the museum of the Institute a valuable collection of antique horological relics and other miscellaneous articles of interest to the watch- and clockmakers' and kindred trades.

The Secretary called attention to a circular received from the Iron and Steel Institute of Great Britain respecting "The Andrew Carnegie Research Scholarship," providing a fund "to enable students who have passed through a college curriculum, or have been trained in industrial establishments, to conduct researches in the metallurgy of iron and steel and allied subjects, with the view of aiding its advance or its application to industry." Candidates, who must be under 35 years of age, may obtain full information from the Secretary of the Institute. There is no restriction as to sex or nationality in the grant of this scholarship.

Mr. C. J. H. Chorman offered a resolution to amend the By-Laws of the Institute by reducing the fee for membership to $5. This was amended by Mr. F. M. Sawyer by a motion to increase the annual dues to $10. Both propositions were referred to the Board of Managers, with the request for an opinion as to their expediency.

Adjourned.

WM. H. WAHL, *Secretary*.

SECTIONS.

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, February 21, 8 P.M. President Morris E. Leeds in the chair. Present, 22 members and visitors.

The paper of the evening was read by Prof. Joseph W. Richards, of Lehigh University. Subject, "Secondary Reactions in Electrolysis." Discussed by Messrs. Reed, Hering, Spencer and others.

The paper was referred for publication.

Stated Meeting, Thursday, March 22. President Morris E. Leeds in the chair. Present, 30 members and visitors.

Mr. Chas. Wirt, of Philadelphia, presented a paper on "Theatre Dimmers and Stage Lighting." The speaker gave an account of the progress that had

been made in this branch of the electrical art, and described certain improvements which he had made in connection therewith. He demonstrated the perfect control that could be obtained over the fly and border lights, and a new application of a dimmer to the projecting lamps which are used in theatre work. (Referred for publication.)

Messrs. Reed, Pawling, Hering and Meeker discussed the paper of the previous meeting, "Secondary Reaction in Electrolysis."

RICHARD L. BINDER, *Secretary.*

Stated Meeting, held Thursday, April 18, 8 P.M. President Leeds in the chair. There were present 74 members and visitors.

The evening was devoted to a communication from Mr. Wm. J. Hammer, of New York, on "Recent European Electrical Progress." The communication, which was profusely illustrated with lantern slides and experiments, consisted of a series of notes and comments upon important electrical developments in Europe, as observed by the speaker at the Paris Exposition, and in the course of a five months' tour through England and the Continent. The following are some of the prominent subjects remarked upon and illustrated: The Nernst lamp; Poulson's telephonograph; the Barmen-Elberfeld suspended electric railway; three-phase railroad work in various countries; utilization of blast furnace gases in gas engines on the large scale; improvements in steam engines, etc.

The speaker received a cordial vote of thanks for his extremely interesting and valuable paper.

WM. H. WAHL, *Secretary pro tem.*

SECTION OF PHOTOGRAPHY AND MICROSCOPY. — *Stated Meeting*, held Thursday, April 4, 1901. Dr. Henry Leffmann in the chair.

The executive committee, which was requested to consider and report upon the proposal to hold a photographic exhibition, made the following preliminary report:

"*To the Section of Photography and Microscopy.*

"The Executive Committee to which was referred the matter of a proposed photographic exhibition, has deemed it advisable to present a preliminary report, in order to secure some expression of opinion as to the scope and nature of the work. As the meeting of the Section in May will be the last prior to the summer recess, time must not be lost by misdirection. In accordance with the expression of sentiment at the meeting in March, Messrs. Samuel Sartain and Frank V. Chambers were added to the committee, as special members with regard to exhibition matters. The committee has held several meetings and has agreed in a general way upon the plan.

"It is proposed that the exhibition shall be comprehensive, including not only all departments of photography, but photographic apparatus, processes, and all methods of picture making by other than light rays strictly so-called. Among the suggestions presented is the following, viz.: to classify the whole subject into three main groups, as follows: Pictorial—Scientific—Applied.

"Under pictorial photography will be comprised landscape, marine portraiture, figure, still-life, genre, etc.

"Under scientific photography will be included apparatus and methods, both of past and present employment, picture making by other than light-rays, and all photographic work adapted rather to research than practical use.

"Under applied photography will be included all adaptations having practical value, such as record work, reproductions of engineering or other drawing, process work, motion pictures, lantern slides, medical and surgical applications of x-rays, micro-photography, photo-micrography and color photography.

"In accepting pictures for the exhibition, the Committee is disposed to consider the general questions of merit either in the practical or technical field and not make any special standard or mode of treatment the sole rule.

"The Committee has given considerable attention to the time and place. It is thought that space might be obtained with nominal cost, at a locality some distance from the Institute; but it is not overlooked that an exhibition at the Institute, if it could be arranged, would be much more satisfactory and advantageous. A great additional attraction would be an exhibition each evening, for about half an hour, of lantern slides, or other general demonstrations in practical matters, and it does not appear that such demonstrations could be carried out so conveniently anywhere as at the Institute.

"The time of the exhibition, it is thought, should be after the first of January 1902, and its duration about three weeks.

"The Committee has not been favorable to the offering of prizes or medals, but believes that certificates of merit or honorable mention might be, with advantage, awarded on uncompetitive judgment.

"It is thought that while no charge should be made for admission some revenue might be derived from the sale of an attractive program or catalogue.

"April 3, 1901."

The report was accepted and ordered to be filed. It was also ordered that the Executive Committee be instructed to confer with the Board of Managers as to the advisability of holding a comprehensive Photographic Exhibition as contemplated in foregoing report, and on the ways and means for carrying the proposition into execution.

An exhibition of lantern slides followed, which embraced among other subjects a series of views of the recently discovered cavern at Mapleton, Pa., made by Mr. W. N. Jennings, and others relating to the Empire of China.

F. M. SAWYER,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, April 10, 8 P.M. Prof. F. L. Garrison in the chair. Present, 42 members and 2 visitors.

The paper of the evening was read by Mr. Richard L. Humphrey, on "The Inspection and Testing of Cements." The communication was an exhaustive historical and technical review of the subject. There was some discussion, chiefly by Mr. Robert W. Lesley and the author.

The meeting passed a vote of thanks to the author, and referred his communication to the Committee on Publications.

G. H. CLAMER, *Secretary.*

SATURDAY NIGHT CLUB OF MICROSCOPISTS.

A reception of the "Saturday Night Club of Microscopists" was held at Franklin Institute Hall on Saturday, December 15, 1900, at 8.45 P.M. There were present, besides the regular Club members, a large number of invited guests. The speaker of the evening was introduced by the President, Dr. Joseph C. Guernsey, with the following remarks: "It is the custom of our Club to occasionally invite outsiders, that they may enjoy with us some of our rich intellectual feasts; and we feel that to-night we are offering an exceptionally entertaining and instructive treat in presenting 'Color Photography.' It has been said to me, 'You are a club of microscopists; therefore, what have you to do with color photography?' I shall refer this question to Mr. F. E. Ives, whose persistent investigations of photography in all its branches, extending twenty years, have culminated in the triumph he is about to exhibit to us. I take sincere pleasure in introducing to you Mr. Frederick E. Ives."

Mr. Ives then proceeded to demonstrate the "kromskop" system of recording and reproducing colors by photography, with special reference to its application in pathology. The importance of color in the diagnosis of many diseased conditions, and the desirability of obtaining and preserving for future reference and study the appearance as to color as well as form in many diseased conditions, having long been felt by the medical world. Both upon the screen and in the kromskops, color photographs of pathological subjects were shown, and also examples of a different character, such as landscapes, portraits and works of art. Mr. Ives gave a concise exposition of the principles of the system, explaining the fact that it bore the same relation to color vision that the moving picture apparatus does to life motion, and the phonograph to sound—each system producing in the first instance, not a reproduction of the thing itself, but a record, which was afterward translated to the eye or ear by means of a special device. A special feature of the demonstration was a description of the methods by which the process, first successful only as a laboratory experiment, has been reduced to such a degree of simplicity and precision that it is coming into general practical use.

The demonstration was followed with great interest by all present, and at the close Mr. Ives was tendered a hearty vote of thanks.

Dr. E R. Snader, on behalf of the Club, moved that a vote of thanks be extended to the Franklin Institute for the use of the hall. It was carried by a unanimous rising vote.

After a short discussion of the subject and questions being answered by Mr. Ives, the Club adjourned on motion.

NATHAN SMILIE, M.D., *Secretary.*